DOCUMENT RESUME

ED 203 088 CE 029 147

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TITLE	Solar Energy. Instructional Materials.
INSTITUTION	University of Central Arkansas, Conway.
SPONS AGENCY	Arkansas State Dept. of Education, Little Rock. Div. of Vocational, Technical and Adult Education.
PUB DATE	[80]
NOTE	85p.; Some diagrams will not reproduce well due to weak print. For related documents see CE 029 144-149.
EDRS PRICE	MF01/PC04 Plus Postage.
DESCRIPTORS	Behavioral Objectives; *Conservation Education; Course Content; Curriculum; *Energy Conservation; Instructional Materials; Learning Activities; Learning Modules; Secondary Education; *Solar Radiation; Test Items; *Trade and Industrial Education; Vocational Education
IDENTIFIERS	*Alternative Energy Sources; Arkansas

ABSTRACT

This document is one of five learning packets on alternative energy developed as part of a descriptive curriculum research project in Arkansas (see note). The overall objectives of the learning packets are to improve the level of instruction in the alternative energies by vocational exploration teachers, and to facilitate the integration of new content on energy into existing vocational programs. Each learning packet contains unit objectives, information, transparency masters, lecture outline, suggested activities, student assignment sheets, tests, and answers to the tests. This unit on solar energy covers the following topics: introduction to solar energy; buying and maintaining solar equipment; basic solar heating system; materials for solar collectors; and passive solar energy (heating). (KC)

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ED203088

SOLAR ENERGY

INSTRUCTIONAL MATERIALS

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UNDER CONTRACT TO

STATE OF ARKANSAS DEPARTMENT OF EDUCATION
DIVISION OF VOCATIONAL, TECHNICAL, AND ADULT EDUCATION

CE 029 147

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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ACKNOWLEDGEMENTS

Appreciation is expressed to the many individuals who gave their time and knowledge in the preparation of this material.

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Sincere appreciation for his help in coordinating the project and supervising financial matters is extended to Dr. Vincent Feck, Director, Center for Vocational Education, University of Central Arkansas.

A special thanks goes to Sonia Bello for proofreading and final typing.

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USE OF THIS PUBLICATION

The overall objective of this publication is to improve the level of instruction in the alternative energies by vocational exploration teachers.

The development of alternative sources of energy and the increasing demand for energy conservation require that vocational educators develop new curriculum and improve existing delivery systems. All vocational education instructors must begin to acquire a minimum background in alternative energy sources and must be prepared to respond in a positive way to the energy education needs within their areas of specialization. It is anticipated that the use of this prepared learning package will facilitate the integration of new content on energy into existing vocational programs.

INSTRUCTIONAL UNIT

This packet contains objectives, information, transparency masters, lecture outline, suggested activities, student assignment sheets, tests and answers to the tests. These materials have been printed on colored paper to code their use. The following key will help easily identify each use by color:

White - teacher instructional materials

Green - information materials, teacher and student use

Yellow - student assignment materials

Golden - tests, teacher controlled

Pink - answers to tests and assignments, teacher use only

One set of each is included in the learning packet. The teacher should reproduce enough of the student use materials to adequately furnish his class with the proper materials.

Objectives

Included in the packet are measurable objectives. These objectives state the goals of the unit of study in such a way that both teacher and student will know what performance is expected.

Information Sheets

Each unit of instruction has information sheets which contain essential facts for that unit. These sheets are coded green and are intended for both teacher and student use. If inadequate information is contained in the student textbook, the teacher may reproduce these sheets for student use.

Instructional Materials

Instructional materials included with the unit contain transparency masters, suggested teaching activities, a lecture outline and a bibliography. These sheets are white and intended for teacher use. Each teacher is encouraged to consider these materials as a starting point and to develop additional activities and teaching materials to meet specific needs.

Student Assignment Sheets

Assignment sheets are included to give students an opportunity to apply knowledge and skill acquired through reading assignments, lecture and practice. These sheets are yellow and may be reproduced for student use.

Tests

A test is included in each unit to enable the teacher to measure student achievement. These sheets are golden and should be reproduced only for testing purposes.

Answers

Answers to student assignments and tests follow each assignment or test. These are coded pink and should be restricted to teacher use only.

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UNIT OBJECTIVES

- To work and experiment with energy systems in order to gain an understanding of energy, sources, conversion, transmission, storage and control.
- To provide an opportunity in which students can gain career information for entry into energy related occupations.

SPECIFIC OBJECTIVES

- The student will demonstrate at an accuracy rating of 75 percent or above, his knowledge of the basic solar heating systems as measured by the tests provided in the curriculum.
- The student will demonstrate, at an accuracy rating of 75 percent or above, his knowledge of the materials for use in the solar collectors and their respective functions.
- The student will be able to state with an accuracy rating of 75 percent or above, the requirements for sizing a solar heating unit and its storage unit.

OUTLINE OF SECTION I

I. INTRODUCTION

II. BUY AND MAINTAIN

III. BASIC SOLAR HEATING

- A. The Collector
  - 1. Air vs. water-cooled collectors
- B. The Storage System
  - 1. Water
  - 2. Air
- C. The Distribution System
- D. The Back-up System

IV. MATERIALS FOR SOLAR COLLECTORS

- A. Absorber Plates
- B. Cover Plates
- C. Insulation for Solar Collectors
- D. The Collector Frames

V. PASSIVE SOLAR ENERGY (HEATING)

- A. The Building as a Collector
- B. The Building as Solar Storage
- C. The Building as a Heat Trap

OUTLINE OF SECTION II (UTILIZATION)

I. SOLAR WATER HEATING

- A. Introduction
- B. Some Types of Solar Water Heaters -
  - 1. Thermosiphon
  - 2. Pressurized pump system
  - 3. Drain-down pressurized pump system

II. SOLAR SPACE HEATING

- A. Introduction
- B. Water-cooled Collectors
  - 1. Use of anti-freeze and water "mix"
- C. The Basic Air System
- D. Retrofitting an Existing Home -
  - 1. Conditions
- E. Sizing Your Solar Heating System -
  - 1. Home heating value chart
  - 2. Examples of fuel-Btu conversion
- F. Sizing the Storage Unit

III. SOURCES

- A. Sources of Solar Equipment
- B. Sources of Solar Information
- C. Sources for this Article

INTRODUCTION

Every 15 minutes, enough solar energy reaches the earth to supply the entire world's energy needs for one year. That is an incredible statement. If this is true, why then do we not make more use of this energy source? There are two reasons why we don't make better use of solar energy. First, solar energy comes to us in a diffuse form. This means that to collect enough of it to do useful work, we have to gather it over a comparatively wide area - and that costs money. Second, solar energy is an intermittent energy source. This means that it is not always there when we need it.

To heat your home by solar energy, you need sunlight collectors that cover the equivalent of roughly half your home's floor area. If you have a 1400 square foot home, you will need 700 square feet of collector area on the roof or appropriate location. The average costs for today's solar collector run about $10.00 per square foot. This puts your collector costs for your 1400 square foot home at $7,000. This estimate does not include the storage and transfer systems.

Up to now, it has been much cheaper to burn fuel in a $1000 furnace than it has been to collect free sunlight in a $9,000 solar heating system. The picture is changing. Every increase in the costs of fossil fuel makes solar energy more attractive and practical.

Various estimates terminate the world reserves of petroleum prior to the year 2025. That means that it is important to begin the education process and changeover to solar energy as soon as possible.

In most situations the average home buyer of today has little knowledge, and even less interest , in the energy consumption of the prospective home he is thinking of buying. His interests lie in the initial cost of the house.

The object of many home builders is to make the house as cheap as possible in order that it will sell faster. They never mention how much it will cost the buyer to maintain his home after he has bought it. Some home builders incorporate some energy saving ideas in their construction as a selling point. The wise buyer will ask questions and make inspections to make sure that the seller's claims are true.

BUY AND MAINTAIN

The more intelligent approach to housing is to look at the lifetime cost of the house. How much will the house cost you to buy and maintain over the life of the house? Would it not make better sense to add solar hardware to a home at the cost of $9,000 if, over the life of the house, the solar equipment will save you $15,000 in heating costs? Would it not make a great deal of sense to buy and have the solar hardware now? Because in 15 to 25 years the fossil forms of fuel may be unavailable.

BASIC SOLAR HEATING SYSTEM

A solar heating system is actually a system of four basic sub-systems:

A. The Collector

B. The Storage System

C. The Distribution System

D. The Back-up System

The Collector

The collector is the heart of any solar heating system. The purpose of the collector is to collect solar energy, transform it into useful heat, and allow that heat to be drawn off for storage. The most common type of collector for space heating - and for water - is the flat-plate collector. At its simplest, the collector is a black plate that absorbs the sun's rays. As the

rays are absorbed, they are transformed into heat.

To draw heat off for use, a fluid, usually water, is circulated through the collector to pick up the heat. Air can also be used to cool the collector. If water is used, there are two popular methods for collecting heat. One, the trickle method, where a stream of water is allowed to trickle down the surface of the plate, and two, by running the fluid through special tubes built into the collector plate. If the heat transfer method is air it may be ducted over or under the plate, or through it if the plate is perforated. Once the heat is picked up it can be carried off to storage.

As soon as the collector plate warms up it will begin to lose heat back to the cool air around it. To prevent this we put insulation in the back of the collector box. To prevent the escape of the heat into the atmosphere in front of the collector, a clear sheet of glass or plastic is placed above the collecting surface. The result is increased efficiency. You do not want the collector to get too hot. The result will be decreased efficiency. Reason: the hotter a collector gets, the more heat it will lose to the surrounding atmosphere. To keep the efficiency high, a heat transfer fluid (water) will be used to pick up the heat as soon as it is collected, before it has a chance to build up and leak away.

Note that a collector is always most efficient when heat is collected and quickly drawn off before it can build up and radiate away.

Ways to assure quick pickup:

1. Always circulate the coldest air or water from the storage back to the collector for reheating.
2. Keep the flow rate high.
3. Use large heat exchangers.
4. Assure good bond between the collector conduits and the collector plate.

Air vs. Water-cooled Collectors

Water-cooled (advantages) -

- More versatile
- Smaller pipes than duct work
- Smaller power requirements
- Higher heat transfer coefficient

Water-cooled (disadvantages) -

- Liquid systems can leak
- Liquid systems are usually more expensive
- Liquid systems can suffer from corrosion and freezing temperatures.

Air-cooled collectors -

If you are interested solely in space heating, air-cooled collectors have advantages. You can take hot air directly from the collectors or from storage and duct it wherever you need it. Air-cooled collectors are simple to adapt to an existing hot-air heating system. Air leakage is not the grave problem that water leakage is. Corrosion is not much of a problem. Your storage system - a concrete and rock bin - will be cheaper than a steel tank of water in most cases. The collectors for air will be cheaper than their water-cooled counterparts.

Air systems can be more efficient. It is difficult to extract heat from water once it drops much below 100 degrees. At that point with a water system, you still have a lot of heat in storage, but you can not get it out. With an air system you can still get useful heat out of a bin of rocks, even with its temperature down to 75 degrees. So with air you run your whole collector system at lower temperatures, and you can get more useful heat out of its storage medium.

One last advantage of an air system is that you will find the air system easier to make.

If you decide to use solar energy to heat your water, go with a separate water heating system, equipped with its own set of water-cooled collectors. But for space heating, favor air-cooled collectors.

The Storage System

Water

Once the heat has been picked up by the heat-transfer medium it is carried off to storage. To use water you need to place a large storage tank in the basement (if you have a basement). If you do not have a basement a suitable location for the tank will have to be found or constructed. Run the water through the collectors via the pipes, then back to storage. With each pass through the collectors the temperature of the water will rise. To extract the heat for use in the home a heat exchanger needs to be installed in the duct system. This will allow the air blown by the fan in the system to circulate over the finned coils of the heat exchanger, thus providing heat for use in the home.

Air

If the heat transfer medium is air, it is easiest to store the heat in a big bin of rocks. The size of the bin will vary in accordance to the size of the house to be heated. The bin needs to be placed in the basement. Again, if you do not have a basement, you will have to make alternative arrangements so that you can store the heat away from the outside elements. The rocks can range in size from fist size to a large pebble. If they are too large they will provide less area for heat exchange. This will force the collectors to operate at a higher temperature and result in lower efficiency. If the rocks are too small, they will pack tightly together and

restrict the flow of air through the bin. Remember to always wash the rocks before putting them into place in the bin.

A duct system is necessary to remove the heated air from the collectors. Once the heated air is removed from the collectors it has to be either used right away or put into storage. To extract the heat from storage, air from inside the home is passed through the rock bin and allowed to return to the house.

The Distribution System

After extracting the heat from storage, you can distribute it throughout the home quite simply. If you are using an air system, just blow the warmed air through the conventional warm air heating ducts.

If you have a liquid heat-transfer medium it is better to run the hot water through a heat exchanger. This allows you to get more useful heat out of your storage water. It also allows you to use the water down to a low temperature. This is important because your storage system is designed to hold a supply of heat for use during the night or on cloudy days when the collectors are not collecting. As you extract heat from storage, the temperature of the water in the tank or the rocks in the bin will drop.

The Back-up System

There will be days when your solar heating system will not be able to provide all the heat necessary to keep the home comfortable. There will be days in the winter when the sun is not able to shine through the winter weather and you will use up all the heat in your storage system. That is when you employ the aid of a "back-up system". A back-up system can be a wood burning stove. It may be the conventional gas or electric furnace.

Whatever is used, it is necessary that it be properly maintained for safe use during those days when the use of the solar heater is not possible.

Most solar heating systems are designed to incorporate the use of a back-up system. A 100 percent solar heating system would be much too costly and extensive for non-commercial use.

MATERIALS FOR SOLAR COLLECTORS

Absorber Plates

The most common materials here are copper, aluminum, plastic, steel, and occasionally a few other materials such as glass or cloth. Copper is by far the best and most reliable material for water-cooled collectors. It provides the best heat transfer. It is the most corrosion resistant. It is easy to work with. The only real drawback about copper is that it costs roughly twice as much as aluminum.

Aluminum may be cheaper but it does have its drawbacks. The biggest problem with aluminum is that it corrodes easily in the fluid-cooled collectors.

In the air-cooled collectors, however, aluminum is the answer. Aluminum's low price and light weight make it an ideal choice. It is easy to work with, an important factor if you plan to build your own collectors.

Note: Aluminum may be used in the trickle down design. This design uses corrugated aluminum sheets to channel the water down its face where it is collected in the bottom by a trough, then sent to storage.

Cover Plates

To improve the efficiency of the solar collector and to protect the absorbing apparatus, a cover plate is installed over the face of the collector. This plate slows the escape of trapped heat. The bigger the difference between the temperature inside and outside of the collector, the more important the cover plate becomes.

Materials Available for Cover Plates

- GLASS - - - - - - - - - - - - breakable but long lasting
- CORRUGATED FIBERGLASS - - - not durable enough
- 3M FLEXGUARD (TM)- - - - - - film 7.5 and 10 mil. excellent choice, durable, easy application, 15 to 20 years life expectancy
- FILON GREENHOUSE MATERIAL (TM) - plastic sheet, available in 50" by 100' rolls, excellent selection, ultraviolet (UV) stabilized
- KALWALL SUNLITE (TM) - - - - excellent selection, similar to FILON GREENHOUSE MATERIAL

3M FLEXGUARD, FILON GREENHOUSE MATERIAL, and KALWALL SUNLITE are, in the writer's opinion, the finest among the materials that could be used as a cover plate. The materials are UV stabilized. This means that the ultraviolet stabilized and that they will not deteriorate due to constant exposure to the sun's ultraviolet rays. These rays affect and break down many plastics.

3M Flexguard is a water clear film. The Filon and the Kalwall are not clear. They are opaque in appearance. They do transmit sunlight as well as glass. The frosty appearance of these two products helps to distribute the light evenly over the face of the collector plate. This frosty appearance also cuts down on re-radiation out of the collector.

These plastics will cost you less than glass depending on what grade or thickness you buy. Working with plastic is much easier than working with glass. Plastics are lighter than glass. Plastics are easier to cut and drill into than glass. Plastics are much more impact resistant, and if it ever does break, plastic does not present a safety hazard.

Insulation for Solar Collectors

For good efficiency, a solar collector must be insulated. A barrier of insulation behind the plate slows heat loss in that direction. Most collectors are not insulated around the edges.

Insulation for a solar collector has to be able to withstand some very high temperatures. A good flat plate collector with double glazing might reach a temperature of over 300 degrees F. under some conditions. That is enough heat to melt many plastic foams. These foams when heated to these temperatures can emit some very poisonous gases. Mineral wools like Owens-Corning Fiberglass make a good choice for insulation. Their weakness is that they provide less insulation value per inch than foams do. Their use may result in a bulkier collector. One way around the problem is to use mineral wool directly behind the plate, then back it up with an inch or so of foam. The wool provides enough insulation to protect the foam, and the foam adds an extra measure of insulation in a compact package.

Collector Frames

Most commercially made collectors have metal frames. Metal is a good choice if you have the facility to work with it to make the collector frame. If you do not have the facility to work with metal, it is suggested that you use -

1. Exterior or marine grade plywood for the back of the collector.

2. K-33 Osmose treated lumber (wolmanized) or redwood for the sides.

PASSIVE SOLAR ENERGY (HEATING)

Much of the general public view solar energy narrowly. That is, as a substitute for fossil fuels. This view would lead us to attach solar collectors to a conventional house and judge its success by any reduction in fuel bills. However, the most direct approach would be to design the building so that it may interact with the climate and interface with the sun's energy directly. This approach is termed "passive" since it does not involve highly technical machinery and controls. It does require more human control than the "active" or high technology systems. The term "solar heated" may be a misnomer when referring to a passively designed system. A more correct term may be "solar tempered".

In order for a building to be a natural solar collector, it must meet three requirements. First, the building must collect heat when heat is needed and reject heat when coolness is needed. Secondly, the building must store heat for the cold times when the sun is not shining. Thirdly, the building should resist rapid changes in temperature.

The Building as a Collector

The primary ways of utilizing the building itself as a collector is by orienting and designing the building to let the sun penetrate through the walls and windows during the winter and by keeping it out during the summer with shading devices such as roof overhang, trees and awnings. The following

generalized guidelines can be utilized to optimize the amount of solar radiation collected by a building.

- The optimum form is a rectangular house elongated along the east-west direction.
- It is important for windows to be oriented south, since windows allow for a greater heat gain than do walls. A heating season gain of 100,000 Btu per square foot of double glass replacing an equal area of south wall with solar overhang has been estimated for the central Arkansas area.
- If heat gain is to be maximized and heat loss minimized, two layers of glass must be used. It is desirable for the windows to be wood framed since the reduction in summer heat gain and winter heat loss for windows framed in wood instead of aluminum is significant.
- Shading must be provided to prevent heat gain during warm months. Exterior shading, overhangs and vegetation, are the most effective while interior shading, curtains and blinds, is the least effective.

The Building as Solar Storage

The building must store heat for cool times when the sun is not shining, and store coolness for warm periods when the sun is shining. Buildings which are built of heavy materials such as stone and concrete do this most effectively. The temperature of a massive structure of concrete, brick or stone does not vary sharply with the varying outdoor temperature since the building provides a large thermal mass. However, these materials with large thermal mass are also poor insulators and to make use of their heat storage capacity, they must be located within the confines of insulation which separates the inside of the building from the outside.

The Building as a Heat Trap

If a building is designed to collect and store heat, it must also be designed to prevent that heat from escaping. Typical homes lose heat in three primary ways.

- By conduction through walls, roof, and floor.
- By convection, the movement of air through the exterior skin of the building; or by infiltration, the passage of air through cracks in the skin of the building

SOLAR WATER HEATING

INTRODUCTION

Probably the best first step for anyone interested in cutting costs of energy consumption with solar heat is to install a solar water heating system. A solar heater for domestic hot water is an easy first step. It is relatively cheap, $1000 - $2000, for a commercial unit; less if you make your own. Payback runs about six years on the average. A good homemade unit may pay for itself in four years.

Unlike solar space heaters, they are easy to tie into existing homes. No matter how poorly insulated, weatherstripped, caulked, or glazed the home might be, a solar water heater will still do the job.

SOME TYPES OF SOLAR WATER HEATERS

The simplest water heater can circulate its own water and regulate its own flow, all without the need for pumps or thermostats. It requires no outside pressure because it delivers heated water by gravity feed. This brings us to our discussion of the first type of solar water heater that uses the principle of thermosiphon.

Thermosiphon

This type of water heater is a marvel of simplicity. It may not be suited to all homes or climates, but where it does work it will "work like a charm".

Basically, the collector construction is the same. The construction consists of header pipes at the upper and lower edges of the collector with risers running between the two. This collector is connected via two pipes to a hot water storage tank, located a minimum of two feet above the collectors. One pipe from the top of the collector connects to the top of the tank.

The other pipe running from the bottom of the collector, connects to the bottom of the tank. As the sun heats the water in the collector, the hot water rises. It runs up the risers to the top header and on to the top of the storage tank. Meanwhile, cold water from the bottom of the storage tank runs through its pipes to the bottom of the collector panel. This water is then heated and begins to rise. Water continually circulates through the panel and up to the tank. The hottest water is always at the top of the tank; the coolest settles to the bottom where it can be picked up and piped off to the collector for heating.

As long as the sun is shining on the collector, the thermosiphon effect continues. As soon as the collector can no longer raise the temperature of the water in storage, the water stops circulating. In effect, you have an automatic differential thermostat controlling the flow.

Warning: If the entire storage tank is not located above the collector, the thermosiphon principle can operate in reverse when the sun goes down. That is, as the water in the collectors cool, it will fall to the tank and set up reverse circulation. Water passing through the collector will cool off and soon all the water in the storage tank will lose its heat. That is why the tank has to be at least two feet above the top of the collector.

To keep the whole system topped off with water, you install a small make-up tank. A toilet tank valve allows water at house pressure to fill this tank, then shuts it off. Now as the water is used, water from the make-up tank enters the system via gravity. Finally, to keep the whole system at atmospheric pressure, and to allow excess pressure to dissipate, a vent pipe runs upward to a point higher than any other point in the hot water system. There the pipe ends. Its end is left open and uncapped.

Pressurized Pump System

Once you install a solar hot water tank below the collector you can no longer rely on the thermosiphon principle. You now need a small pump to circulate water through the collector. A pump system needs a regulating system. A twin sensor is added to the unit along with a differential thermostat. One sensor will check the temperature of the hot water in storage. The other will check the temperature in the collector. If the collector water is hotter than the storage water, the differential thermostat will turn the pump on. But if the collector water is cooler than the storage water, the thermostat will shut the pump down. This prevents the hot water from circulating through the collector at night or during cloudy spells.

Drain-down Pressurized Pump System

This system allows for the automatic draining of the system should the outside temperature get too cold. The drained fluid may go outside the system or be run back into storage.

SOLAR SPACE HEATING

INTRODUCTION

Solar water heating may be the first logical step in our switch from fossil fuels to solar energy, but solar space heating is the biggest and most important step. The typical home uses four times as much energy to heat the interior as is needed to heat the water used for daily consumption. The dollar benefit of switching to solar heating can be rather large.

The expense of solar space heating can be rather large also. Solar experts place the cost of a new home built with solar heating about $6000 above the cost of a similar home without it.

WATER-COOLED COLLECTORS

Water-cooled collectors are the most common form of space heating being used today.

The heart of the system is the solar collector. These collectors are placed on the roof in most cases, facing south, and tilted up from the horizontal at an angle equal to your latitude plus 10 to 15 degrees. The extra 10 or 15 degrees favor collection during the winter over summer collection, by pointing the collectors more directly at the low winter sun. The area covered by the collectors is roughly equal to half the floor space of the home.

For the most reliability, the collectors should be copper. If they can not go on the roof, they should be placed on the ground or on a fence.

Use of Anti-freeze and Water "Mix"

To pick up the heat gathered by the collectors, you pump a solution of anti-freeze and water through the collectors via a system of CPVC (chlorinated-polyvinyl chloride) plastic pipes. These CPVC pipes withstand hot temperatures. They lead down to the basement. There they enter the heat storage tank filled with 1500 gallons of water. The heat carried by the anti-freeze solution is then transferred to the water in storage by means of a heat exchanger.

Specifics: To circulate the heat transfer solution, the pump should be capable of circulating water at a rate of about 15 gallons per minute, and it should be designed to handle hot water. You can make your own exchanger by connecting 10 or 15 lengths of three-quarter inch copper pipes 10 feet in length. Use U-bent fittings to connect the runs of pipe, laying them out in a serpentine pattern, or simply use a 150 foot coil of three-quarter inch copper tubing.

You need a differential thermostat to control the pump that drives the collection loop. The Deko Labs TC Series or one of the Rho Sigma thermostats will do the job. To connect

it, epoxy one sensor to the back of one of the collector panels, and surround it with insulation. Fasten the other to the pipe leading out of storage and back up to the collectors. Surround the sensors with insulation so that it is sensing only the temperature of the water in the pipe, not the air around it. Then hook up the switching terminals to the pump.

If you are starting with a new home, the best tank would be one in poured concrete, placed underneath the basement floor. If that is not possible, a steel tank inside the basement is the next choice. A tank outside the home is a poor choice since any heat it loses will be wasted.

Your system can now collect heat and carry it off for storage. Now it needs a means to extract that heat and put it to use warming the home. The solution is to pump the water through a finned-tube heat exchanger, then to blow air over the exchanger, and to route the heated air throughout the home through the conventional warm air heating ducts. If the job requires the addition of solar heating equipment to a home that already is equipped with a warm air heating system, the job will be easy. You can use the fan and ductwork already present in the current system. All you have to do is have a sheet metal man place a finned-tube, liquid to air heat exchanger into the system. You can feed water to this unit with a small pump. Pick this water up near the top of the storage tank where the water is the hottest for consumption as the occupants need it. A thermostat of the type used in conventional home heating applications does the job of controlling the unit. When it calls for heat it should turn on both the pump feeding the liquid-to-air heat exchanger and the furnace fan as well.

With this arrangement you can use the conventional warm air furnace as a back-up. Whenever the solar system can not do the job, a second thermostat set a few degrees below the solar thermostat, will start the back-up conventional heating system. This second thermostat should be wired to shut off the first one whenever the second cuts in.

THE BASIC AIR SYSTEM

This system is quite similar to the water system of space heating. But air takes the place of water. Ducts replace pipes. A bin full of rocks replaces the storage tank. Yet the principle remains the same.

An electric blower feeds air to the collectors through insulated ducts. This blower should be capable of supplying air at a rate of around three cubic feet per minute, per square foot of collector. Thus, if you have 500 square feet of collector, the blower should be able to move about 1,500 cubic feet per minute. This is a common capacity for the typical ½ horsepower heating and ventilating blower such as the Dayton K4C117. The blower has adjustable speeds so you can regulate flow for best operation.

The air blown through the collector is ducted down in a closed loop to the basement where it passes through the storage bin full of rocks. From there the air is ducted back to the collectors for reheating. Hot air from the collectors should enter the storage bin at the top and exit at the bottom. Thus, the coolest air in storage is always returned to the collectors to keep efficiency high.

This air flow is controlled by the usual differential thermostat. One probe of the thermostat is epoxied to the back of the collector plate; the other can be placed inside the storage bin -- or you can epoxy it to the duct leading out of storage back to the collectors. Both probes should be insulated to ensure they sense only the temperature of the collector or duct, not the surrounding air. If your storage probe goes inside the bin, no insulation in necessary.

Extracting heat from storage is simply a matter of blowing house air through the bin of hot rocks. The huge surface area of the rocks inside the bin provides ample heat exchange. The air flow for this extraction system should be the reverse of that for the collection air. That is, the air should enter the bin at the bottom, pass through the bin, and be drawn off for distribution

from the top. A separate blower is usually used to move the air through this distribution network of insulated ducts.

Note: To utilize this system a series of dampers is required to be installed into the system. This damper system must be worked out by a trained heating and airconditioning man.

A conventional warm air furnace can be used for back-up heating requirements. One may also look at the practicality of using a wood stove to heat the house during those periods of extended bad weather when the sun does not make its way through.

RETROFITTING AN EXISTING HOME

For most people, the big question about solar heating is, "Can my home be heated by the sun?" The answer in many cases is yes. The answer must be qualified by stating the condition and design factors of the home. Most homes today would require major improvements before solar equipment could be installed. Some home owners may be required to change their landscaping before solar equipment is installed. The following is a list of important conditions that must be met before you can expect economical performance from any type of solar heating equipment.

Conditions

a. You will need some place to put the collectors. This should be an area open to direct sunlight all day long during the winter months.

b. The collectors should face directly south, or as much as 15 degrees to the west of south.

c. The collectors should be tipped back at the top so that they form an angle with the horizontal equal to the latitude of your site plus 10 to 15 degrees.

d. The roof is the most popular location for the collectors. This puts them out of the way where they are less susceptible to damage than they would be on the ground.

e. Make sure that the home is as energy efficient as you can afford to make it.

f. Adequate sunlight is a most important requirement. Arkansas is a state that has an adequate supply of sunshine.

g. Space for the storage medium is necessary. It is preferable to place all storage in the basement.

SIZING YOUR SOLAR HEATING SYSTEM

Home Heating Value Chart

To determine the heating load of your present home, check your fuel consumption records from the past years. (This section applies to those individuals that have lived in one place for a minimum of two years.)

Once you have obtained the records, refer to the FUEL VALUE CHART below. With the aid of the FUEL VALUE CHART, you can calculate your heating requirements in Btu's per heating season.

Fuel Value Chart

Butane - - - - - -	103,600 Btu per gallon
Propane - - - - - -	91,000 Btu per gallon
Natural Gas - - - -	700 Btu per cubic foot
Electricity - - - -	3,412 Btu per kilowatt-hours

Examples of Fuel-Btu Conversion

a. Should you use 200 gallons of propane per month for 4 months during the winter heating season, your Btu per month expenditure would be 18,200,000 Btu's. If you match Btu's collected against Btu's required, you will come up with a system that provides about 70 percent of your heating needs, not 100 percent. Why? You will not get 100 percent efficiency because you will have a 30% loss in your storage and distribution system.

b. Should you use 200 gallons of butane per month for 4 months during the winter heating season, your Btu per month expenditure would be 20,600,000 Btu's. If you match Btu's collected against Btu's required you will come up with a system that provides about 70 percent of your home heating needs.

c. Should you use 594 kilowatt-hours of electricity per month for

a 4-month period during the winter heating season, your Btu expenditure would be 3,412 x 594 = 2,026,728 Btu's.

The estimated Btu collection potential for the solar equipment is available from the manufacturer. If you build it yourself, you may be only able to obtain a guestimate of the Btu collection potential.

SIZING THE STORAGE UNIT

In most residential applications, a tank of 1500 to 2000 gallons will do the job, should you decide to use water as the storage medium. If you choose rock, 15 to 20 tons of rock will do the job. A ton of gravel is roughly equal to a cubic yard, and a cubic yard is 27 cubic feet. Therefore, 20 tons of rock will occupay about 540 cubic feet or a bin measuring 6 feet high, 12 feet long and 8 feet wide.

Note: Water has a thermal capacity of 8.34 Btu per gallon for each degree Fahrenheit rise in temperature. For a 1000 gallon storage tank, if the storage water temperature is raised from 90 degrees F. to 190 degrees F., then 834,000 Btu's will be stored.

SOURCES

SOURCES OF SOLAR EQUIPMENT

Air

International Solarthermatics
Box 397
Nederland, CO 80466

Solaron Corp.
4850 Olive St.
Denver, CO 80022

Sunworks
Box 1004
New Haven, CT 06508

Liquid

Energex Corp.
481 Tropicana Rd.
Las Vegas, NV 89109

Energy Systems, Inc.
941-D Anistad Court
El Cajon, CA 94063

Grumman Aerospace Corp.
South Oyster Bay Rd.
Bethpage, NY 11714

Martin-Marietta Corp.
11300 Rockville Pike
Rockville, MD 20852

Reynolds Metals
2315 Dominguez St.
Torrance, CA 90508

Sunsource
9606 Santa Monia Blvd.
Beverly Hills, CA 90210

* Nabholz Supply
Exchange Avenue
Conway, AR 72032

* This supply outlet has the films available for cover plates (Flexguard and Filon Greenhouse Material). It has the expanded aluminum and the black coatings for the collector interior, and also has a mirror-like adhesive backed film called Scotchcal made by the 3M company.

SOURCES OF SOLAR INFORMATION

Books

Title: Energy Primer: Solar, Water, Wind and Biofuels, ed. Richard Merrill et al.
From: Portola Institute
540 Santa Cruze Avenue
Menlo Park, CA 94025
Cost: $4.50
Covers experiments, manufacturer, and equipment. An excellent resource for designing and building energy systems. It also has a multitude of addresses.

Title: Handbook for Homemade Power, Mother Earth News Staff
From: Bantam Books
414 E. Golf Rd.
Des Plains, IL 60016
Cost: $2.25
Covers several areas of energy and sources for additional information.

Title: Producing Your Own Power: How to Make Nature's Energy Sources Work for You, ed. Carol H. Stoner
From: Vintage Books (Random House)
457 Hahn Rd.
Westminster, MD 21157
Cost: $3.95
Covers several areas such as wind, solar and wood. It also shows small scale designs for practical uses.

Title: Future Energies by Roy Meador
From: Ann Arbor Science Publications
P.O. Box 1425
Ann Arbor, MI 48106
Cost: $1.95
Provides a summary of future energy prospects for humankind with emphasis on the most promising sources,

Title: Energy for Survival: The Alternative to Extinction by Wilson Clark
From: Total Environmental Action
Cost: $4.95
Widely acclaimed for its encyclopedia coverage of both the potential of the many alternative energy sources as well as the limits of the traditional sources.

Note: The following is a source for a lot of free material. It is sponsored by the government and almost all publications are free or are available at a nominal cost.

The Energy Research & Development Administration
P.O. Box 62
Oak Ridge, TN 37830

SOURCES FOR THIS ARTICLE

(1) Energy and Education: Teaching Alternatives
Fredrick E. Posthuma Ed., National Education Association Publication, Washington D.C. (1978)

(2) Home Energy How-To
A.J. Hand, Harper and Row, New York, (1977)

(3) Solar Energy In America
William D. Metz and Allen L. Hammond, American Association for the Advancement of Science, Washington D.C. (1978)

(4) Sun Power, An Introduction to the Applications of Solar Energy
J.C. McVeigh, Pergamon Press, New York. (1977)

ABSORBER OR ABSORBER PLATE - the part of a solar collector that receives the incident solar radiation and transforms it into thermal energy.

ACTIVE SOLAR HEATING SYSTEM - an assemblage of collectors, storage devices, and distribution equipment which converts solar energy into heat and distributes the heat in a controlled manner.

AIR-BASED SOLAR HEATING SYSTEM - a system in which air is heated in a solar collector and is used to transfer heat to the rest of the system.

AIR-CONDITIONING - treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet the requirements of the conditioned space.

AIR-SOURCE HEAT PUMP - heat pump that transfers heat from outdoor air to indoor air during the heating season. This is the most common type of heat pump installed in homes.

AMBIENT AIR - any unconfined portion of the atmosphere, the outside air.

ANGLE OF INCIDENCE - angle between a ray striking a surface and a line perpendicular to that surface at the point of impact. Normal or perpendicular rays have zero angle of incidence.

APERTURE - opening or projected area of a solar collector through which the solar radiation is admitted and directed to the absorber.

AUXILIARY ENERGY SUB-SYSTEM - equipment using conventional energy sources to supplement the output provided by the solar energy system.

BRITISH THERMAL UNIT (Btu) - heat required to raise the temperature of one pound of water by one degree Fahrenheit.

BUILDING OVERALL HEAT LOSS RATE - overall rate of heat loss from a building by means of transmission plus infiltration.

CALORIE - one calorie is equal to 4.2 joules. Originally, the amount of heat required to raise the temperature of one gram of water by 1 degree C. was considered to be a calorie.

CELSIUS - temperature scale based on the freezing and boiling point of water (0 degree and 100 degree, respectively). The name Celsius has replaced the name Centigrade in most scientific usage.

CLIMATE - prevailing or average weather conditions of a geographic region as shown by temperature and meteorological changes over a period of years.

COLLECTOR EFFICIENCY - ratio of the energy collected by a solar collector during a time period to the radiant energy incident on the collector in the same time period.

COLLECTOR SUB-SYSTEM - assembly used for absorbing solar radiation, converting it into useful thermal energy, and transferring the thermal energy to a heat-transfer fluid.

COMPONENT - smallest identifiable element of a solar heating or cooling sub-system such as a valve, a control, or a container.

CONCENTRATING COLLECTOR - solar collector that contains lenses, reflectors, or other optical elements for concentrating the radiation falling on the collector aperture onto an absorber area smaller than the aperture.

CONTROLS - devices such as thermostats and temperature-sensing elements used to manipulate fans, pumps, and dampers in solar systems.

CONVECTION - transfer of heat from one place to another by actual motion of a heated fluid.

COVER PLATE - transparent material covering the aperture of a solar collector. Purpose is to reduce heat loss from the absorber to the surroundings and to protect the absorber.

DECLINATION - angular position of the sun north (plus) or south (minus) of the plane of the earth's equator. It is a function of the time of year.

DESIGN LIFE - period of time during which a heating or hot water system is expected to function without requiring major maintenance or replacement.

DIFFUSE INSOLATION - sunlight scattered by atmospheric particles and gases. It arrives on the earth's surface from all directions and cannot be focused.

EFFICIENCY - ratio of the useful energy output to the energy input under certain conditions, expressed in percent.

ENERGY - capacity for doing work. Its various forms such as thermal (heat), mechanical (work), electrical, and chemical can be transformed from one into another. It is measured in kilowatt-hours (Kwhr) or British thermal units (Btu), or in joules (J), where 1 joule equals 1 watt-second.

ENERGY CONSERVATION - reduction in the energy used.

ENERGY CONVERSION - changing one form of energy to another.

ENERGY EFFICIENCY - amount of useful work or product, divided by the fuel or energy input. In electrical generation, it is the amount of electricity produced per unit of fuel consumed.

FIRST LAW OF THERMODYNAMICS - conservation law which says that the total energy of a closed system is constant (energy can be transformed but not created or destroyed).

FLAT PLATE (COLLECTOR) - device used to collect solar energy in which the surface absorbing the incident solar radiation is essentially flat. No concentration of sunlight is employed - the absorber is about the same size as the aperture.

FRESNEL COLLECTOR - type of concentrating solar collector which uses a Fresnel lens to focus solar radiation.

FRESNEL LENS - thin piece of plastic or glass containing tiny, carefully shaped grooves whose surfaces retract incoming light as desired, usually to a point or line focus.

GREENHOUSE EFFECT - trapping heat inside a glass or plastic enclosure, or trapping heat by the earth's atmosphere, primarily by reducing convective heat loss.

HEAT EXCHANGER - device used to transfer heat from one material to another, usually between two separate fluids.

HEAT GAIN - heat gained by a building from the sun, internal heat sources, and, in warmer weather, from infiltration and conduction through the building skin.

HEAT LOSS - heat loss from the building by conduction through the windows, walls, roof, floors or foundation, and by the infiltration of air.

HEAT PUMP - reversed (or reversible) airconditioning device employing refrigeration equipment in a manner that enables usable heat to be supplied to a space during winter and extracted from the space during summer.

HEAT SOURCE - a body which supplies heat energy. A heat pump uses air or water outside a structure as a heat source during its heating cycle.

HELIOSTAT - a device that orients a mirror to reflect sunlight in a specific direction, regardless of the sun's position in the sky.

INFILTRATION - inward air leakage through cracks and joints in any building element and around or through windows and doors of a building. It is caused by the pressure effects of wind and/or the effect of differences in the indoor and outdoor temperatures.

INSOLATION - radiation received from the sun, including ultraviolet, visible, and infrared. Total insolation includes both direct and diffuse radiation.

INTERNAL GAIN - combined heat release from all heat sources in a building other than the heating system. Major sources include lighting, people, machinery, and combustion.

JOULE (J) - unit of energy equal to the work done by a force of one newton moving an object one meter in the direction of the force. Equivalent to one watt-second.

KELVIN (K) - temperature scale whose degrees are equal to degrees on the Celsius scale but whose zero point is at the "absolute zero" of temperature, at which all molecular motion theoretically ceases. On the Kelvin scale, the freezing point of water is about 273 C. and the boiling point about 373 C.

KILOWATT - unit of power that measures the rate at which energy is produced or used. Ten 100-watt light bulbs use energy at the rate of one kilowatt (equal to 1000 watts). A rate of one kilowatt maintained for one hour produces or uses one kilowatt hour of energy (equal to 1000 watt-hours).

LAMINATED GLASS - two or more sheets of glass held together by an intervening layer or layers of plastic material.

LANGLEY - unit of solar radiation intensity equivalent to 1.0 gram-calorie per square centimeter.

PARABOLIC FOCUSING COLLECTOR - type of concentrating collector which focuses beam radiation by means of a reflector having a parabolic cross section.

PASSIVE SOLAR HEATING - heating a building through use of the sun plus appropriate architectural details and construction techniques, and with the aid of very little (or no) mechanical equipment or energy.

PEBBLE BED or ROCK BED - large bin of rocks of uniform size used for storing solar heat in air-type heating systems.

PHOTOVOLTAIC CELL - semiconductor device in which the absorption of light creates a separation of electrical charges. This results in an electrical potential that can be tapped by allowing electrons to flow through an external circuit. The net effect is the direct conversion of light into electricity.

POWER - rate at which energy is used or work is done, measured in ft-lb/sec., horsepower, or watts.

RETROFIT - installation of solar water heating and space heating/cooling systems in buildings not originally designed for solar use.

RETURN ON INVESTMENT - market discount rate that will result in zero life cycle savings.

SENSORS - devices such as pressure transducers, thermocouples, and flowmeters used to detect changes in a system.

SOLAR ABSORPTANCE - ratio of the amount of solar radiation absorbed by a surface to the amount of radiation incident upon it.

SOLAR COLLECTOR - device designed to absorb incident solar radiation and transfer the energy to a fluid flowing in thermal contact with the absorbing surface.

SOLAR ENERGY - energy transmitted from the sun.

SOLAR FURNACES - solar concentrators for producing very high temperatures. Installations in France, Russia, and Japan have attained temperatures as high as 7000 degrees. F.

SOLAR HEATING SYSTEM - assembly of sub-system and components necessary to convert solar energy into thermal energy for heating purposes, in combination with auxiliary energy when required.

STORAGE CAPACITY - the amount of energy that can be stored by a solar heating system for use at a later time.

TEMPERATURE - a property by which objects are ranked according to the direction of heat flow between them when they are placed in contact.

THERMOSIPHON - circulation of a fluid by convection, which occurs in a closed system as warm (less dense) fluid rises and cooler (more dense) fluid falls.

THERMOSTAT - an instrument that measures temperature, and controls devices for maintaining a desired temperature.

TRACKING COLLECTOR - a collector that can rotate about one or two axes to face the sun. This is usually restricted to high-temperature concentrating collectors because of the complexity and cost of the tracking system.

WATER-AIR HEAT EXCHANGER - device in which air is either heated or cooled by flowing water.

INSTRUCTIONAL MATERIALS

I. LIST OF COMPONENTS FOR A 32 SQUARE FOOT SOLAR COLLECTOR AND ESTIMATED COST

A. Water-cooled

B. Air-cooled

II. DIAGRAMS

A. Air-cooled Collector

B. Water-cooled Collector

Diagrams of Solar Systems -

C. Solar Window Unit

D. Separated Heating Module

E. Solar Heated Home

F. Controls for a Proposed Solar House

G. Passive Solar Design

III. SUGGESTED ACTIVITIES

IV. LECTURE OUTLINE

LIST OF COMPONENTS FOR A 32 SQUARE FOOT SOLAR COLLECTOR AND ESTIMATED COST

Water-cooled

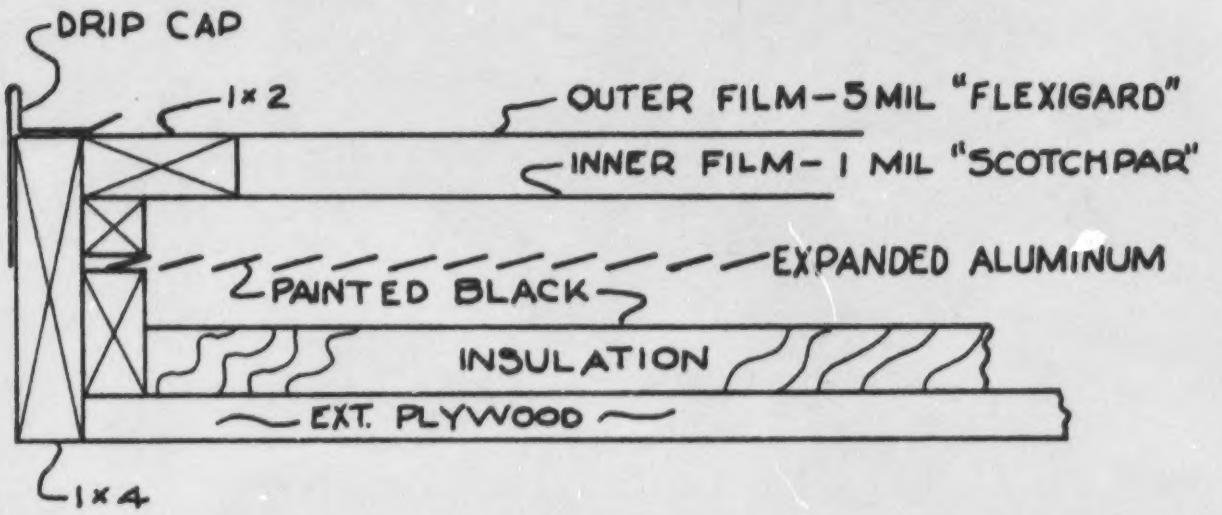
Quantity	Description	Est. Cost
Collector box		
1 sheet	3/4" x 4' x 8' exterior plywood	$ 22.00
50 ft.	1" x 4" osmose (TM) pine or plain pine	12.50
1 sheet	½" double foil face insulation board, 4' x 8'	7.50
1 sheet	1/32 x 4' x 8' galvanized metal	17.00
32 square ft.	3½" fiberglass insulation	2.00
Collector surface		
100 ft.	½" copper tubing	50.00
24	½" copper ells	6.00
1 lb.	solder	9.00
24	½" tubing clamps	5.00
Cover sheet		
1 sheet	5 mil. or 7.5 mil. 3M Flexiqard (TM) or Filon (TM) Greenhouse Material 50" x 9' or glass	25.00
Fastening and flashing		
8 oz. can	waterproof glue	1.50
1 tube	silicone caulk	4.50
1 qt	oilbase exterior enamel	4.00
1 lb.	6p cement coated nails	.50
30 ft.	galvanized drip cap	6.00
		$ 162.50

LIST OF COMPONENTS FOR A 32 SQUARE FOOT SOLAR COLLECTOR AND ESTIMATED COST

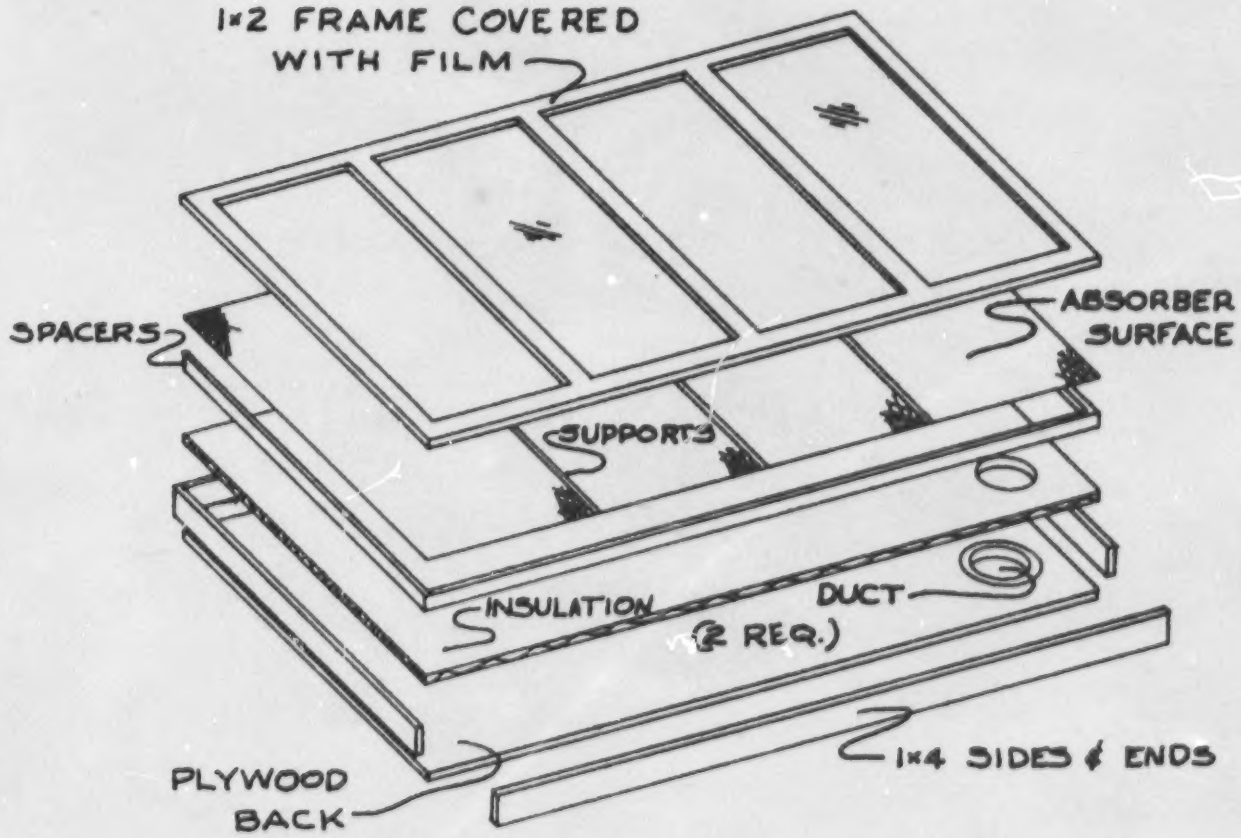
Air-cooled

Quantity	Description	Est. Cost
Collector box		
1 sheet	3/4" x 4' x 8' exterior plywood	22.00
50 ft.	1" x 4" osmose (TM) pine or plain pine	12.50
1 sheet	½" double foil face insulation board, 4' x 8'	7.50
1 sheet	1/32" x 4' x 8' galvanized metal	17.00
32 square ft.	3½" fiberglass insulation	2.00
Collector surface		
4 sheets	2' x 4' expanded aluminum	40.00
4 pcs.	4' aluminum butt joint moulding	6.00
3 cans	Farathane (TM) Bar-B-Q black high temperature paint	9.00
Cover sheet		
1 sheet	5 mil. or 7.5 mil. 3M Flexiqard (TM) or Filon (TM) Greenhouse Material 50" x 9' or glass	25.00
Fastening and Flashing		
1 8-oz. can	waterproof glue	1.50
1 tube	silicone caulk	4.50
1 qt.	oilbase exterior enamel (black)	4.00
1 lb.	6p cement coated nails	.50
30 ft.	galvanized drip cap	6.00
		$ 157.50

DIAGRAM A. AIR COOLED COLLECTOR

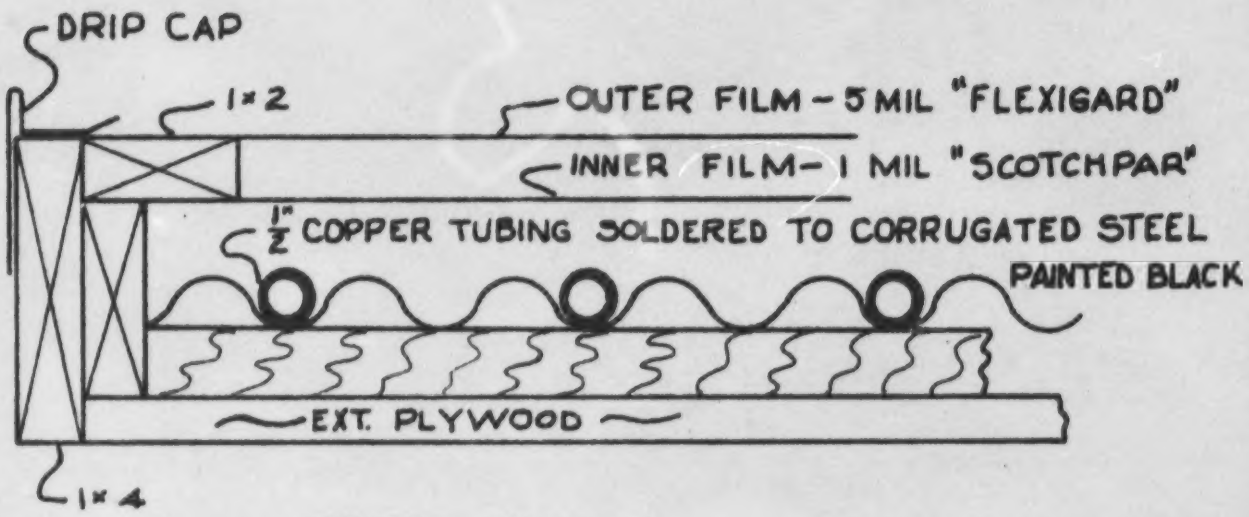


CROSS SECTION



EXPLODED VIEW

DIAGRAM B WATER COOLED COLLECTOR



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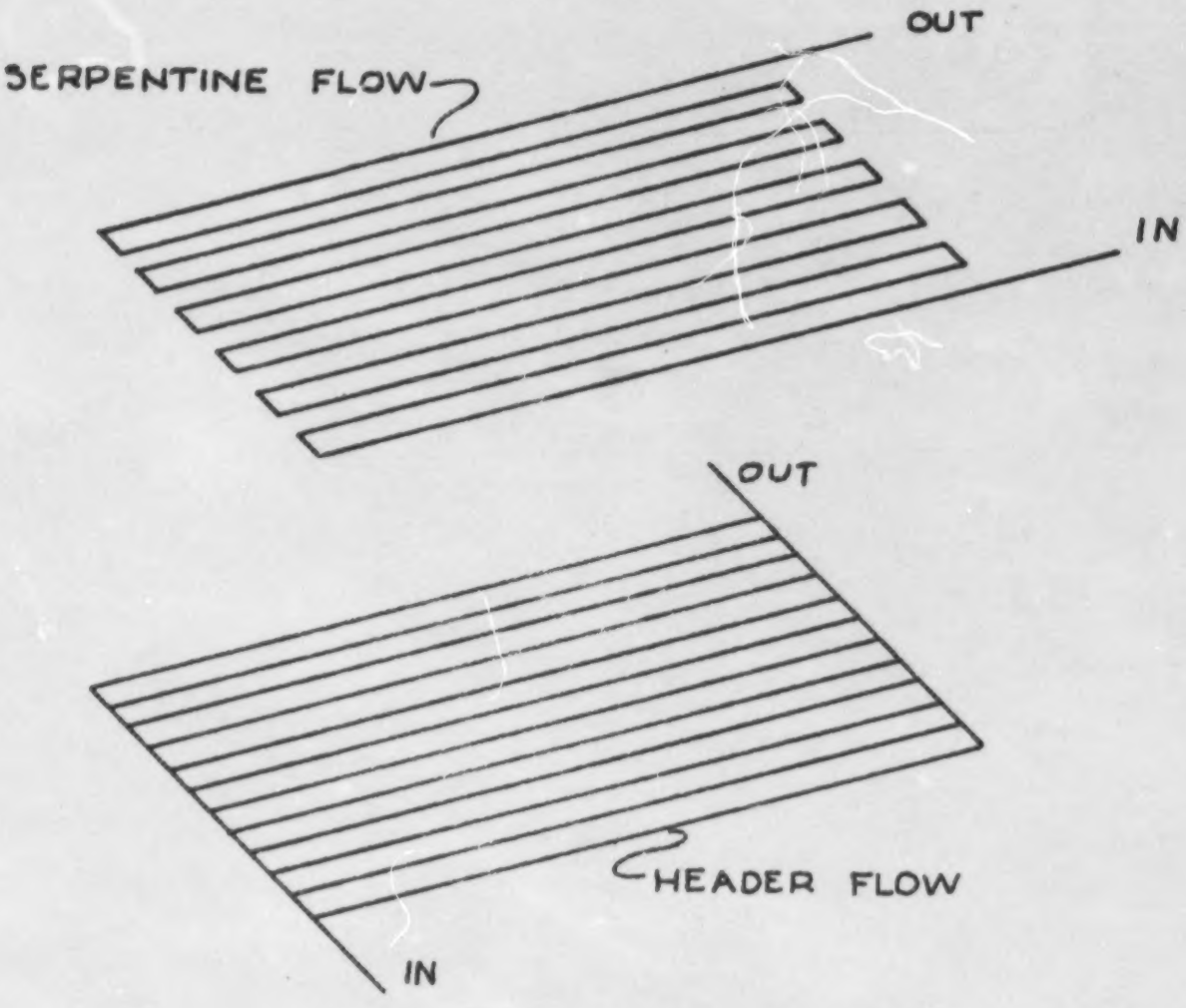


FLOW PATTERNS

DIAGRAM C. SOLAR WINDOW UNIT

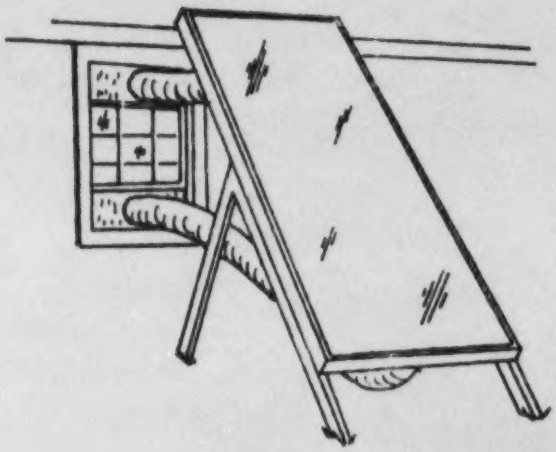
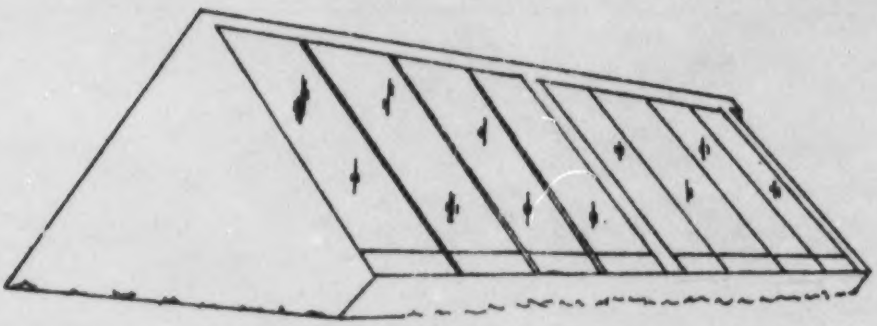


DIAGRAM D. SEPARATED HEATING MODULE



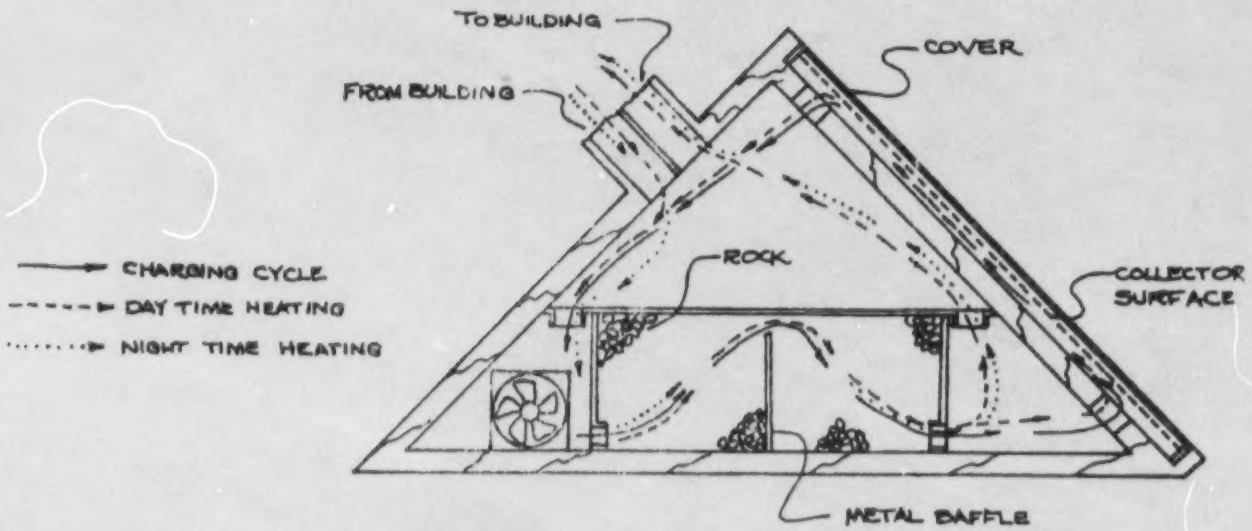


DIAGRAM E SOLAR HEATED HOME

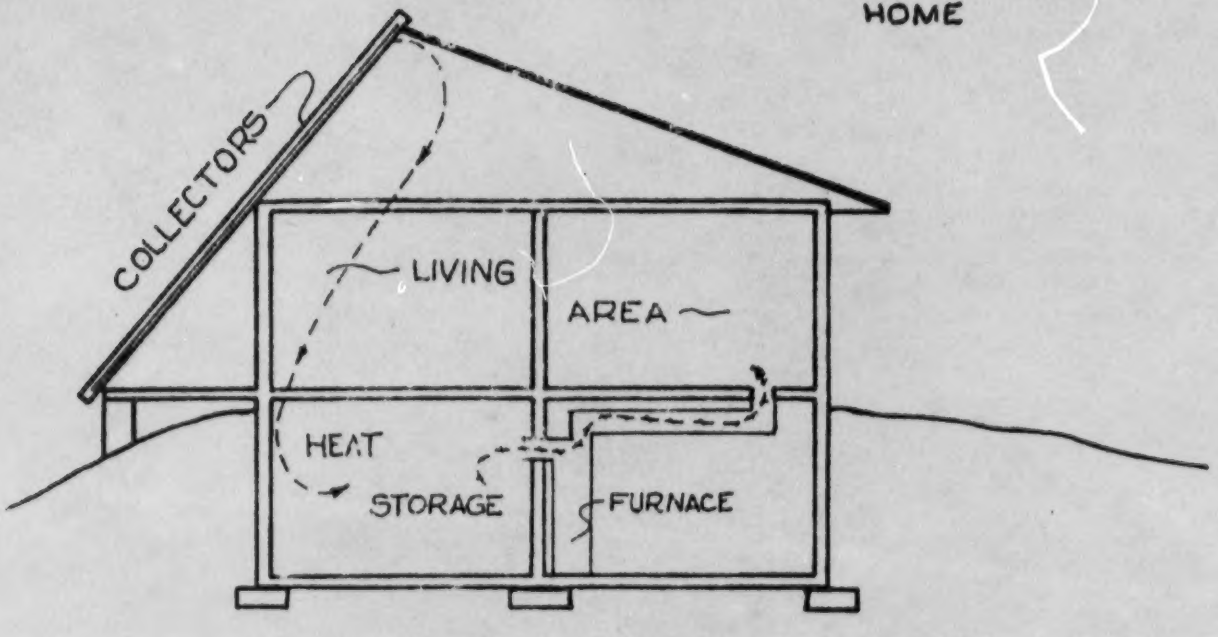
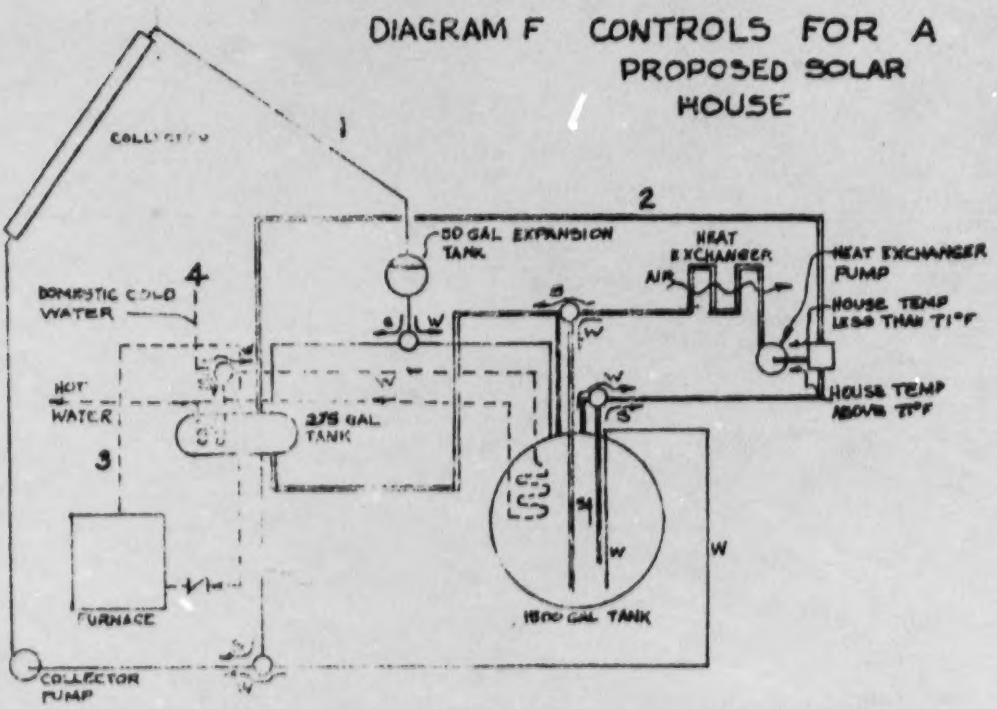
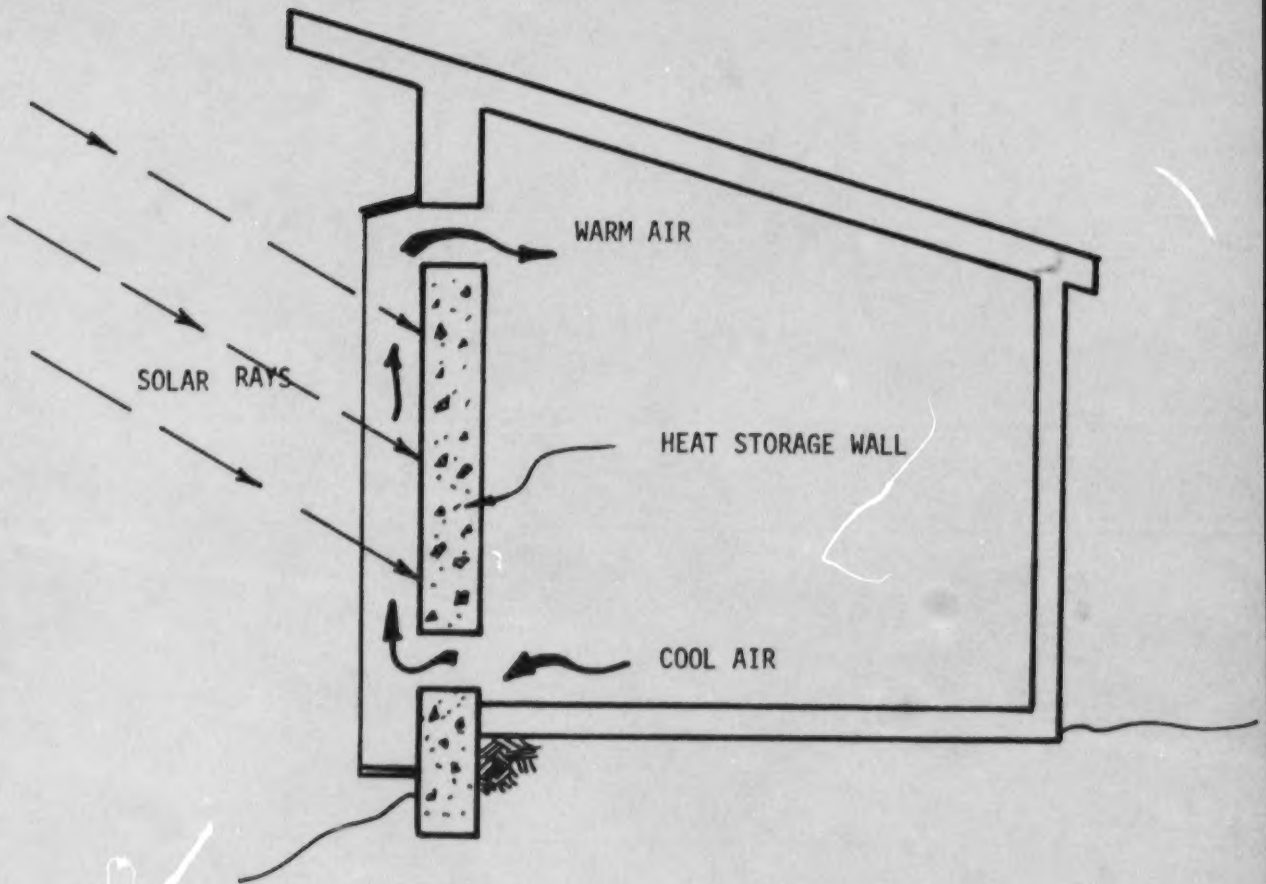


DIAGRAM F CONTROLS FOR A PROPOSED SOLAR HOUSE



1. Collector Circuit, Pump on when sun shines, 2. Heat exchanger circuit, heat pump controlled by house thermostat, 3. Furnace circuit, keeps 275 gal. tank at 135°, 4. Domestic hot water circuit.

DIAGRAM G. PASSIVE SOLAR DESIGN



PASSIVE SOLAR DESIGN

SUGGESTED ACTIVITIES

A. Invite a guest speaker who is currently using solar energy related material in his home to speak to the class.

B. Invite a business representative from a company that sells or installs solar heating equipment to speak to the class.

C. Form a discussion group to discuss the current trends in solar energy activities. Each group should be assigned a topic and a specific date for presentation.

Suggested topics:

1. BIG SOLAR - the power tower approach to electricity production.
2. SMALL SOLAR - the use of solar power by the individual.
3. Photovoltaic research.

D. Construct a flat plate air-cooled collector. Class project.

E. Construct a flat plate water-cooled collector. Class project.

F. Field trip to a home that has solar heating equipment.

G. Demonstration of solar heating equipment arranged through Arkansas Power and Light's "Energy Van" Public Information Department.

LECTURE OUTLINE

Section I - Information

I. INTRODUCTION

A. Every 15 minutes, enough solar energy reaches the earth to supply the entire earth's energy needs for one year.

B. Solar energy comes to us in a diffuse state.

C. Solar energy is an intermittent energy source.

D. A solar collection system will require collector area equal to half the amount of square foot floor space in a home. More if the home is not well insulated or if the collectors are not very efficient.

E. Solar heating systems can cost from $1000 to $10,000 or more.

F. Various estimates terminate the world's reserves of petroleum prior to the year 2025.

G. In most situations the average home buyer has little knowledge of energy saving features.

II. BUY AND MAINTAIN

A. It is more intelligent to look at the "life costs" of a home.

B. In 15 to 25 years fossil fuels may be unavailable.

III. BASIC SOLAR HEATING SYSTEM

A. The Collector

B. The Storage System

C. The Distribution System

D. The Back-up System

A. The Collector

1. The collector is the heart of any solar heating system.

2. The most common type of collector for space heating is a flat plate collector.

3. At its simplest, a collector is a black plate that absorbs the sun's rays.

4. As soon as a collector plate warms up it will begin to lose heat back to the surrounding atmosphere.

5. To keep efficiency high, a heat transfer fluid will be used to pick up the heat as it is collected, before it has a chance to build up and leak away.

6. For increased collector efficiency:

   a. Always circulate the coldest air or water from the storage back to the collector for reheating.

   b. Keep the flow rate high.

   c. Use large heat exchangers.

   d. Assure good bond between collector conduits and the collector plate.

Air vs. water-cooled collectors

Water-cooled - <u>advantages</u> -

a. More versatile.

b. Smaller pipes than ductwork.

c. Smaller power requirements.

d. Higher heat transfer coefficient.

Water-cooled - <u>disadvantages</u> -

a. Liquid systems can leak.

b. Liquid systems are usually more expensive.

c. Liquid systems can suffer from corrosion and freezing temperature.

Air-cooled collectors -

If you are interested only in space heating, air-cooled collectors have advantages.

a. You can take hot air directly from the collectors or from storage and duct it wherever you need it.

b. Air-cooled collectors are simple to adapt to an existing hot air heating system.

c. Air leakage is not the grave problem that water leakage is.

d. Corrosion is not a problem.

e. The storage system is less expensive than a water tank system.

f. Air systems are easier to make.

B. The Storage System

1. There are two types of storage systems:

a. Water (liquid) -

1) Best location for storage is the basement.

2) Place the heat exchangers in the warm air duct system.

b. Air -

1) Storage is usually a large bin filled with rocks.

2) Rock should be no larger than fist size or smaller than large gravel.

3) If the rocks are too small, they will pack tightly together and restrict air flow through the bin.

4) If the rocks are too large, they will provide less area for heat exchange.

5) Remember to wash the rocks before they are placed into the bin.

6) A duct system is necessary.

2. Once the heat is removed from the collector it has to be either used or stored.

3. To extract the heat from storage, air from inside the home is passed through the rock bin and allowed to return to the house.

C. The Distribution System

1. After extracting the heat from storage, you can distribute it by blowing the warm air through the conventional warm air heating system.

2. You may use the heat directly from the collectors by passing the air through the conventional warm air heating system's ducts.

3. If you have a liquid heat transfer medium it is better to run the hot water through a heat exchanger.

4. As you extract heat from storage, the temperature of the water in the storage tank will drop. The same for the rock bin.

D. The Back-up System

1. A back-up system is used only when the weather will not allow sufficient sunlight.

2. A back-up system can be:

a. Wood stove.

b. Wood central heating system.

c. Conventional electric central heating system.

d. Electric baseboard heaters.

e. Gas furnace.

f. Oil furnace.

3. Most solar heating systems are designed to incorporate the use of a back-up heating system.

IV. MATERIALS FOR SOLAR COLLECTORS

A. Absorber Plates

1. The most common materials used in the absorber plates are copper, aluminum, and plastic.

2. Copper is by far the best and most reliable material for a water-cooled collector.

3. The only real drawback about copper is that it is about twice as expensive as aluminum.

4. Aluminum is cheaper than copper.

5. Aluminum corrodes easily.

B. Cover Plates

1. To improve the efficiency of the solar collector and to protect the absorbing apparatus, a cover plate is installed over the face of the collector.

2. The bigger the difference between the temperature inside and outside the collector, the more important the cover plate becomes.

3. Materials available for cover plates:

   a. GLASS - - - - - - - - - - breakable but long lasting

   b. CORRUGATED FIBERGLASS- - not durable enough

   c. 3M FLEXIGARD (TM)- - - - excellent choice, film is ultraviolet (UV) stabilized

   d. FILON (TM) GREENHOUSE MATERIAL - - sheet plastic, UV stabilized, excellent choice

   e. KALWALL SUNLITE (TM) - - excellent choice, UV stabilized

C. Insulation for Solar Collectors

1. For good efficiency, a solar collector must be insulated.

2. Most collectors are not insulated around the edges.

3. Insulation used in collectors has to be able to withstand some very high temperatures.

4. If foam is incorporated in the design of a collector and it gets too hot there is a danger that the foam will emit a poisonous gas.

5. Mineral wools like Owens-Corning Fiberglas (TM) make a good choice for insulation.

6. One may incorporate the use of fiberglass wool to help protect the foam insulation in a solar panel.

D. Collector Frames

1. Most collector frames are made of metal if they are commercial products.

2. Wood is used in most homemade collectors.

3. Use ½" or 3/4" marine or exterior plywood for the panel backing.

4. Use K-33 Osmose (TM) treated lumber for the sides.

5. You may also use redwood for the sides of the collector panel.

V. PASSIVE SOLAR ENERGY (HEATING)

A. Passive solar design is that design that allows a building to interact with the climate and interface with the sun's energy directly.

B. Passive solar heated homes require less technical control and more human control.

C. The building must collect heat when heat is needed and reject heat when coolness is needed.

D. The building must store heat for the cold times when the sun is not shining.

E. The building should resist rapid changes in temperature.

F. The building is the collector.

G. The building is its own storage.

H. The building is designed to collect and store heat; it must also prevent heat from escaping.

LECTURE OUTLINE

Section II (Utilization) - Information

I. SOLAR WATER HEATING

A. Introduction

1. The best first step for anyone interested in cutting costs of energy consumption is to install a solar water heating system.

2. $1000 to $2000 for commercially constructed solar water heating units. The cost may go down if you make the system yourself.

3. Payback runs on an average of about six years.

4. No matter how poorly insulated a home may be, a solar water heating system will still do the job.

B. Some Types of Solar Water Heaters

1. Thermosiphon - simplest water design.

2. Pressurized pump system.

3. Drain-down pressurized pump system.

II. SOLAR SPACE HEATING

A. Introduction

1. Solar space heating is the biggest and most important step in American housing design.

2. The typical home uses four (4) times as much energy to heat the interior as is needed to heat the water used for daily consumption.

3. The expense of solar space heating can be rather large. Solar experts place the cost of a new home built with solar heating about $6000 above the cost of a similar home without it.

B. Water-cooled Collectors

1. Water-cooled collectors are the most common form of space heating being used today.

2. The heart of the solar heating system is the solar collector.

3. The collectors should face south. The tilt should be up from the horizontal at an angle equal to your latitude plus 10 to 15 degrees.

In Arkansas the latitude is close to 35 degrees. Add 10 to the 35 degrees to get an overall tilt of 45 degrees.

4. The square foot covered by the collector is equal to ½ the square foot floor space in the home (heated floor space).

5. For the most reliability, the collector's absorber plate should be made of copper.

6. A system may utilize an anti-freeze and water "mix" solution to keep the pipes from freezing during the winter.

7. If you are starting with a new home, the best tank for storage would be one in poured concrete, placed underneath the basement floor.

8. If a tank poured in concrete is not possible, a tank located inside the basement is the next choice.

9. A storage tank located outside the home is a poor choice, since any heat it loses will be wasted.

10. Use a finned-tube type heat exchanger in the duct system to transfer the heat from storage into the home heating system.

11. You will need two thermostats. One thermostat is needed to control the solar equipment. The other is needed to turn the solar equipment off and turn the conventional heating system on.

C. The Basic Air System

1. This system is similar to the water system of heating, but air takes the place of water. Ducts take the place of pipes. A bin of rocks replace the liquid storage tank.

2. An electric blower feeds air to the collectors through insulated ducts. This blower should be capable of supplying air at a rate of around three cubic feet per minute, per square foot of collector.

3. Hot air from the collector should enter the storage bin at the top and exit at the bottom. Thus, the coolest air in storage is always returned to the collectors to keep efficiency high.

4. The air flow in the system is controlled by a "differential" thermostat.

5. Placement of the thermostat probes: one probe of the thermostat is epoxied to the back of the collector plate; the other can be placed inside the storage bin or epoxied to the duct (inside the duct) leading out of storage back to the collectors.

6. Heat extraction from storage is simply a matter of blowing house air through the bin of hot rocks.

7. To utilize the air system, a series of dampers is required to be installed into the warm air heating system.

8. Back-up for the solar heating system could be a conventional warm air heating system or a simple wood stove.

D. Retrofitting an Existing Home

1. Most homes could be heated by the sun. Most homes that fall into this category of being potentially able to be heated by the sun would need extensive remodeling and weatherization.

2. Conditions for retrofit:

   a. You will need some place to put the collectors. This should be in direct sunlight all day long during the winter months.

   b. The collectors should face directly south.

   c. The collectors should be tipped back at the top so that they form an angle with the horizontal equal to the latitude site plus 10 or 15 degrees.

   d. The roof should be the location for the collectors.

   e. Make the home as energy efficient as affordable.

   f. Adequate sunlight is a most important requirement.

   g. There must be a place for storage. It is preferable to place all storage in the basement.

E. Sizing Your Solar Heating System

1. To determine the heating load of your present home, check your utility bills from the past years. If this information is not available you may be able to obtain it from the local utility. Once you have the information, you can calculate the Btu requirement per month during the heating season. On most commercially produced collectors, there will be a Btu output rating. This rating is used for your calculations of just how many collectors you will need for heating purposes.

2. If you construct your own system, try to have ½ the square feet area in collectors as you have in square feet of heated interior area. In some cases it may be necessary to have more collector surface because of the reduced efficiency of many "homemade" collectors.

F. Sizing the Storage Unit

1. A 1500 to 2000 gallon tank is required for most residential applications that use a liquid storage medium.

2. If you use rock, 15 to 20 tons of washed rock will usually do the job of storage for an air storage solar heating system.

3. Water has a thermal capacity of 8.34 Btu per gallon for each degree Fahrenheit rise in temperature. For a 1000 gallon storage tank, if the storage water is raised from 90 degrees F. to 190 degrees F., 834,000 Btu's will be stored.

III. SOURCES

A. Sources of Solar Information

Books

Title: Energy Primer: Solar, Water, Wind and Biofuels, ed. Richard Merrill et al.
From: Portola Institute
540 Santa Cruze Avenue
Menlo Park, CA 94025
Cost: $4.50
Covers experiments, manufacturer, and equipment. An excellent resource for designing and building energy systems. It also has a multitude of addresses.

Title: Handbook for Homemade Power, Mother Earth News Staff
From: Bantam Books
414 E. Golf Rd.
Des Plains, IL 60016
Cost: $2.25
Covers several areas of energy and sources for additional information.

Title: Producing Your Own Power: How to Make Nature's Energy Sources Work for You, ed. Carol H. Stoner
From: Vintage Books (Random House)
457 Hahn Rd.
Westminster, MD 21157
Cost: $3.95
Covers several areas such as wind, solar and wood. It also shows small scale designs for practical uses.

Title: Future Energies by Roy Meador
From: Ann Arbor Science Publications
P.O. Box 1425
Ann Arbor, MI 48106
Cost: $1.95
Provides a summary of future energy prospects for humankind with emphasis on the most promising sources,

Title: Energy for Survival: The Alternative to Extinction by Wilson Clark
From: Total Environmental Action
Cost: $4.95
Widely acclaimed for its encyclopedia coverage of both the potential of the many alternative energy sources as well as the limits of the traditional sources.

Note: The following is a source for a lot of free material. It is sponsored by the government and almost all publications are free or are available at a nominal cost.

The Energy Research & Development Administration
P.O. Box 62
Oak Ridge, TN 37830

III. SOURCES

B. Sources for this Article

(1) Energy and Education: Teaching Alternatives
Fredrick E. Posthuma Ed., National Education Association Publication, Washington D.C. (1978)

(2) Home Energy How-To
A.J. Hand, Harper and Row, New York, (1977)

(3) Solar Energy In America
William D. Metz and Allen L. Hammond, American Association for the Advancement of Science, Washington D.C. (1978)

(4) Sun Power, An Introduction to the Applications of Solar Energy
J.C. McVeigh, Pergamon Press, New York. (1977)

SECTION I

1. How much energy reaches the earth every 15 minutes?
2. How does solar energy get to the earth? Where does it come from? In what form does the solar energy arrive?
3. Does the sun shine all the time during the heating season?
4. What is meant by the term "heating season"?
5. What is the necessary ratio of collector to floor space?
6. What kind of information would you consider important if you were a prospective home buyer?
7. What will a wise home buyer look for and do?
8. How long will our fossil fuels last (projected estimate)?
9. What type of solar collector is the most popular and why?
10. What will happen if you do not use a cover plate over your absorber plate?
11. Name some considerations necessary in making a collector efficient?
12. Know about the circulation of both air and water.
13. What is the purpose of the heat exchanger? What type is most efficient when installed in an existing warm air heating system?
14. Name and be able to explain the operation of the two types of storage mediums covered in the text material.
15. What are the advantages of a water-cooled collector system?
16. What are the disadvantages of a water-cooled collector system?
17. What are the advantages of an air-cooled collector system?
18. What are the disadvantages of an air-cooled collector system?
19. What is meant by the term "passive solar heating system"?
20. What direction should the windows of a home that incorporates passive solar design characteristics face?
21. What are the most common materials used in the construction of the absorber plate?
22. What is a cover plate? What is the function of the cover plate? Name some materials used in the construction or installation of the cover plate.

23. Why is it necessary to insulate a solar collector?

24. What might happen to foam insulation in a collector panel if the temperature got too hot?

25. Be able to name the suggested materials for the construction of the collector box frame.

SECTION II

1. What would be the best first step in cutting costs of energy consumption?

2. What does the term "payback" mean?

3. Name and be able to discuss three types of solar water heaters.

4. What will happen if the storage tank used in the "thermosiphon" type solar water heating system is not located at least two feet above the collectors?

5. What is the ratio of space heating to water heating in the normal non-solar heated home?

6. What are the tilt requirements for the placement of solar collectors on the roof of a home?

7. What type of metal is the most reliable for use in water-cooled collector?

8. Why is a finned tube heat exchange preferred as a means of placing heat into the duct system?

9. Be able to discuss the:

   a. collection process

   b. heat storage process

   c. heating from storage process.

10. What devices are used to control the flow of air in air-cooled system?

11. List some important considerations that must be met before you can expect economical performance from any type of solar heating equipment.

12. Be able to tell how to size a rock bin storage system for a 1500 square foot heated home.

13. What is the thermal capacity for each degree Fahrenheit rise in temperature?

ASSIGNMENT NO. 1

1. Draw a reasonable representation of (name each) three types of concentrating solar energy collectors.

A.

B.

C.

ASSIGNMENT NO. 2

1. Draw a reasonable representation of a flat plate (air type) collector and name the component parts.

   Make drawing below.

ASSIGNMENT NO. 3

1. Draw a reasonable representation of a flat plate collector (liquid type) and name the component parts.

   Make drawing below.

ASSIGNMENT NO. 4

1. Write a one page summary on the design and implementation of a passive solar energy system.

   Write summary below.

ASSIGNMENT NO. 5

1. Write a one page summary on the design and implementation of an active solar energy system.

   State answer below.

ASSIGNMENT NO. 6

1. Relate the information necessary for sizing a solar energy system to a home that is two years old when the fuel consumption bills are available.

   For comparison, the fuel used in the home is electricity. The average consumption for the 4-month heating season is 600 Kwhr. The size of the home is 1500 square feet heated.

   State answer below.

ASSIGNMENT NO. 7

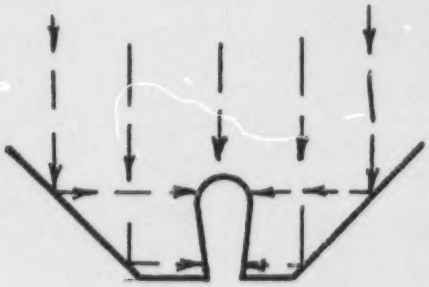
1. What would be necessary to take into consideration if you were trying to decide to install a solar heating system in a home that was 15 years old?

   State answer below.

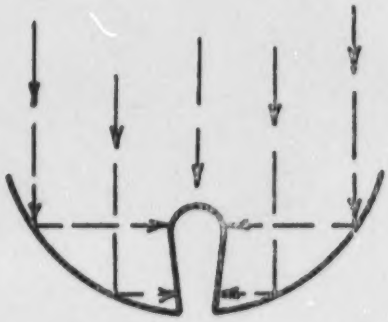
ASSIGNMENT NO. 1

1. Draw a reasonable representation of (name each) three types of concentrating solar energy collectors.

   Shown below are four types of concentrating solar collectors. Only three were asked of students.

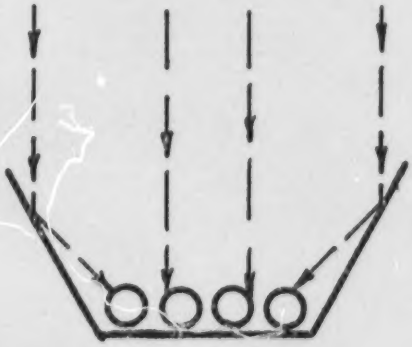


Mouchot



Ericsson

Abbot

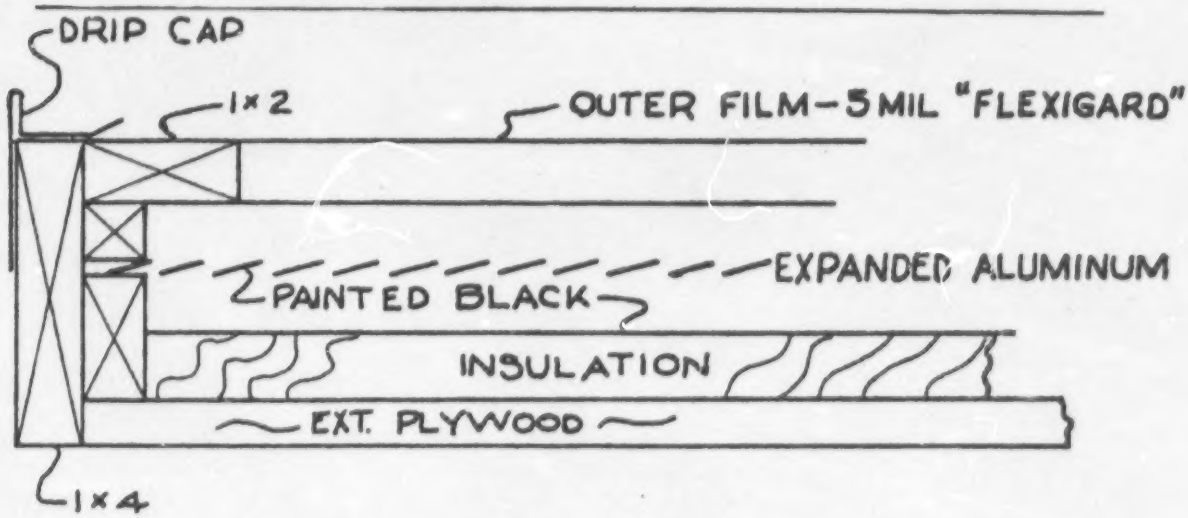


Somer

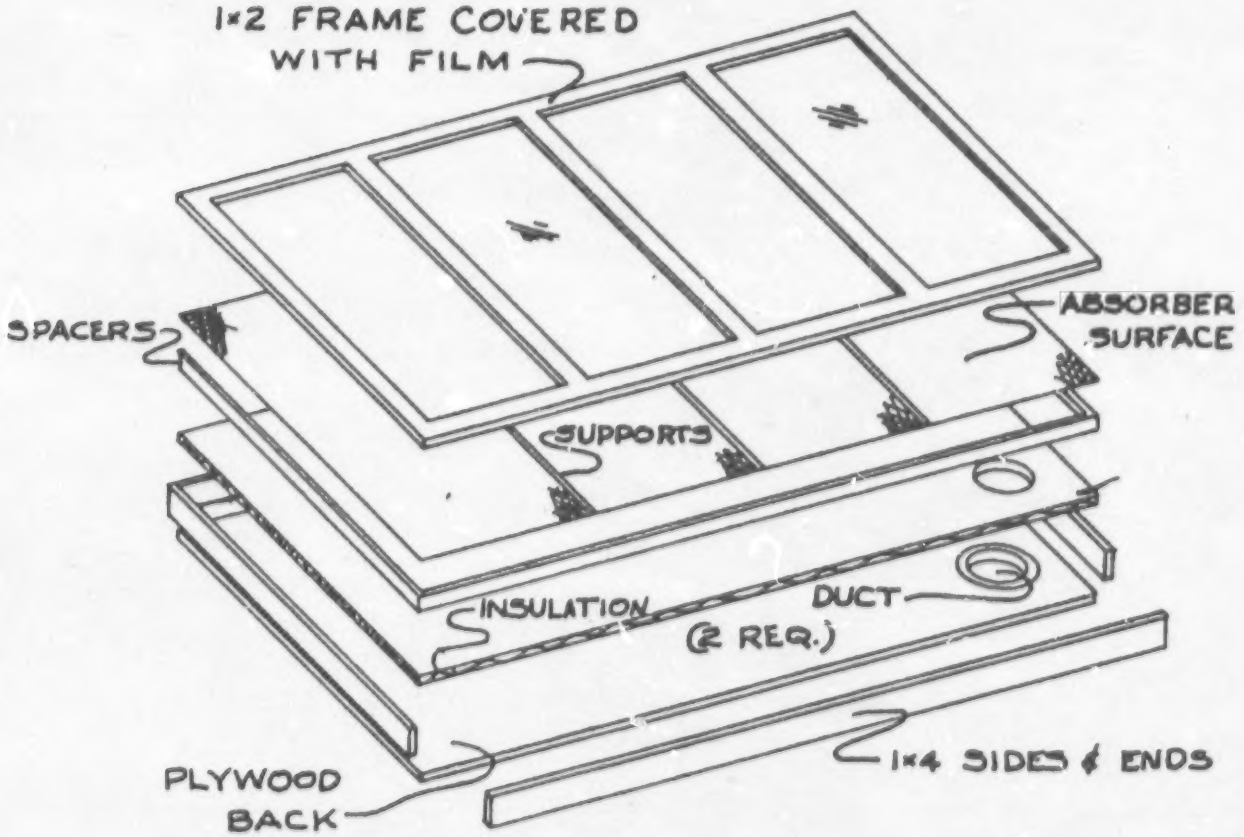
Concentrators. Concentrators focus a large area of radiation from the solar disk upon a small absorbing surface by means of flat reflecting or refracting surfaces. The absorbed heat is removed by a flowing or evaporating fluid. Concentrators can reach very high temperature. This type of collector must follow the sun across the sky. It can only use the sun's direct rays.

ASSIGNMENT NO. 2

1. Draw a reasonable representation of a flat plate (air type) collector and name the component parts.



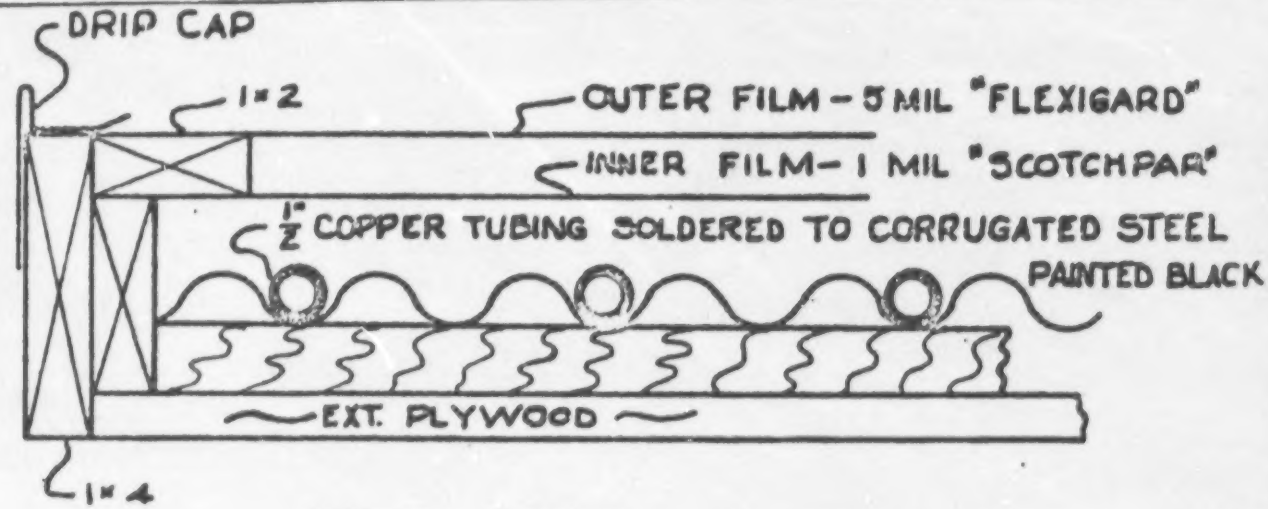
CROSS SECTION



EXPLODED VIEW

ASSIGNMENT NO. 3

1. Draw a reasonable representation of a flat plate collector (liquid type) and name the component parts.



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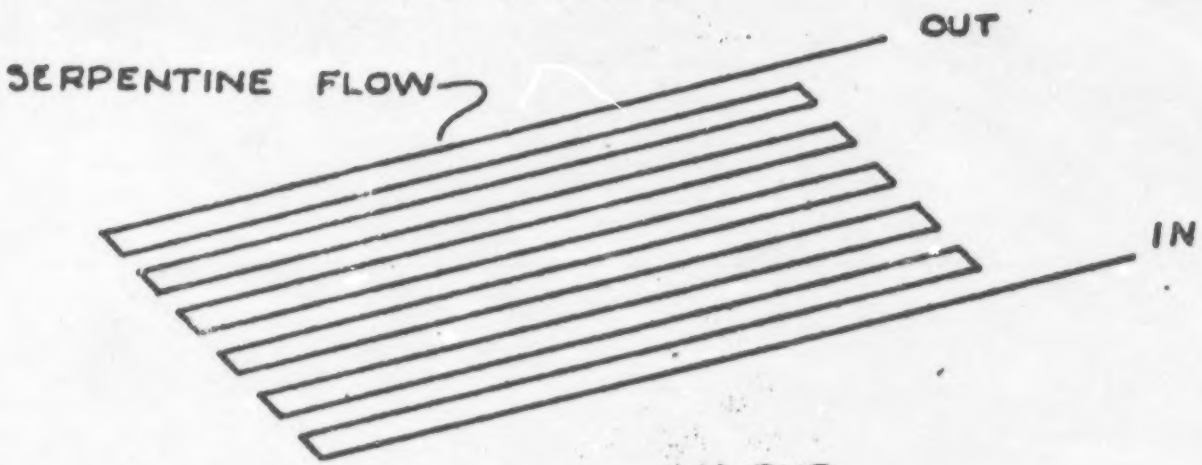
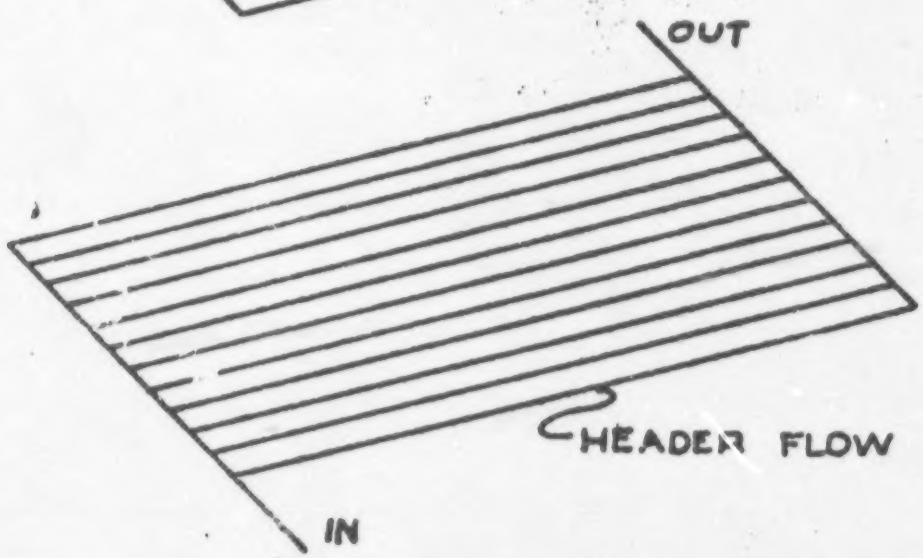




FLOW PATTERNS

ASSIGNMENT NO. 4

1. Write a one page summary on the design and implementation of a passive solar energy system.

   Note: a drawing of a simple passive solar design is on the next page.

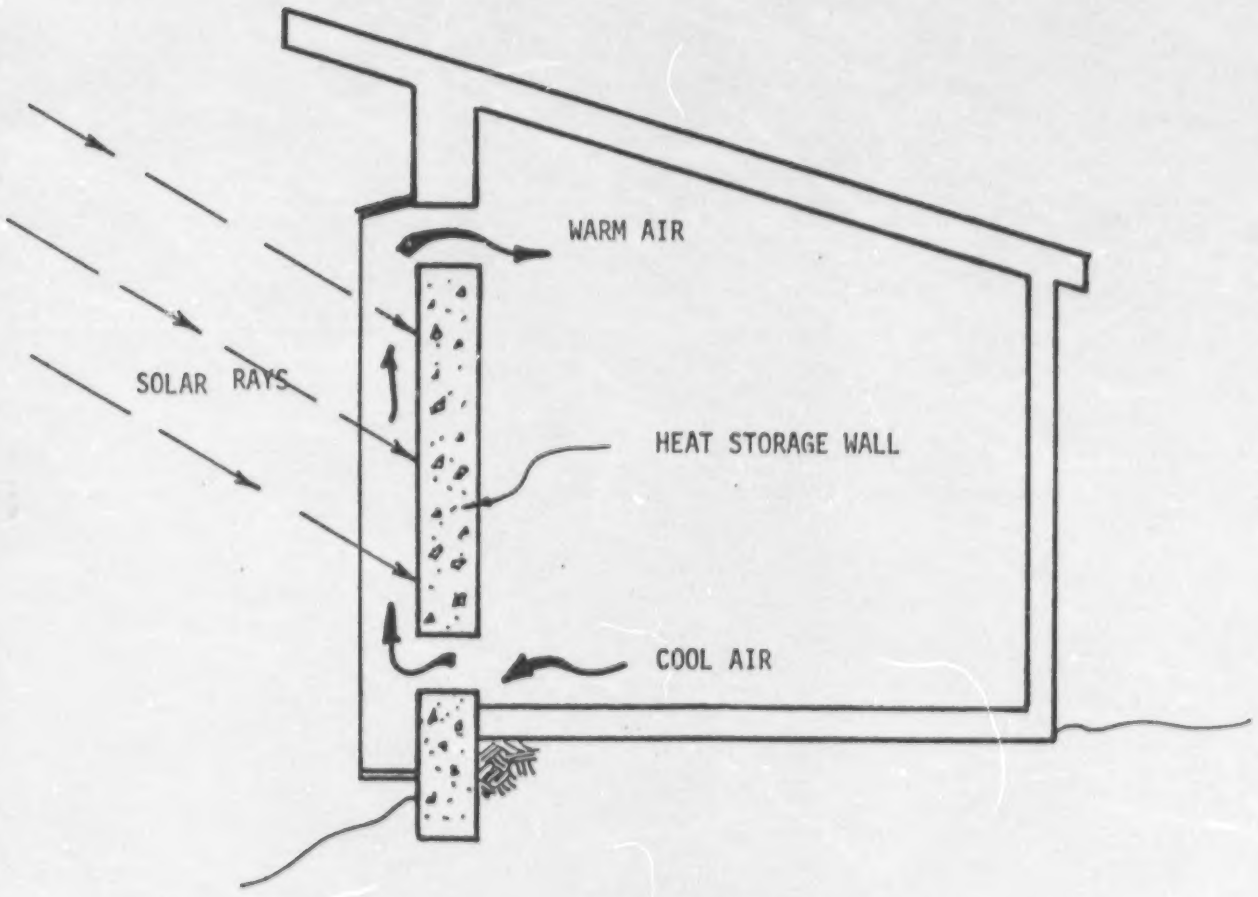
A "passive" solar energy system does not employ highly technical machinery. In order for a building to be a natural solar collector, it must meet three requirements:

1. First, the building must collect heat when heat is needed and reject heat when coolness is needed.
2. Secondly, the building must store heat for the cold times when the sun is not shining.
3. Thirdly, the building should resist rapid changes in temperature.

Guidelines for passive solar architecture:

1. The optimum form is a rectangular house elongated along the east-west direction.
2. It is more important for windows to be oriented on the south side.
3. Double glazed windows must be used.
4. Shading must be provided to prevent heat gain during the warm months.

ASSIGNMENT NO. 4



PASSIVE SOLAR DESIGN

ASSIGNMENT NO. 5

1. Write a one page summary on the design and implementation of an active solar energy system.

A typical solar energy system usually consists of four basic components:

1. The Collector
2. The Storage System
3. The Distribution System
4. The Back-up System

The collector is the heart of the solar collector system. Many different types of collectors have been developed, with the most common being the flat-plate collector. The flat-plate collector is the simplest to construct, to mount, and has a very long life expectancy.

Liquid or air can be used to circulate through the collector to pick up the heat. If water is used, there are two popular methods for collecting heat: the trickle method and the method of running the fluid through special tubes built into the collector plate. If an air collector is used, the air usually passes under the absorber plate where it is heated. The air usually flows under rather than over the absorber plate to reduce the heat loss through the transparent cover sheet. The flow rate for air is usually 2 to 3 cu ft per minute per square foot of collector.

Some advantages of air over liquid systems are:

1. Freezing and corrosion problems are not present.
2. Longer lifetime for collectors.
3. A i r leaks will not cause damage to the structure.
4. Air from the collector can be used directly as room heat.

The main disadvantage is that air storage systems require greater storage volume.

The size of the storage needed depends upon the size of the collectors. As a rule of thumb, for water storage, 1.25 to 2.5 gal. per square foot of collector is needed, and for air, .5 to 1 cubic foot of rock per square foot of collector is needed.

ASSIGNMENT NO. 6

1. Relate the information necessary for sizing a solar energy system to a home that is two years old when the fuel consumption bills are available.

   For comparison, the fuel used in the home is electricity. The average consumption for the 4-month heating season is 600 Kwhr. The size of the home is 1500 square feet heated.

Note these inclusions in the answer:

1. A minimum of 750 square feet of collector area is necessary for 70% efficiency.

2. A 1500 to 2000 gallon water storage tank is necessary if water is the chosen storage medium.

3. A 15 to 20 ton rock storage bin filled with large gravel will be necessary if the storage medium is for a system that uses air to transfer the heat.

4. A collection system capable of collecting 2,057,000 Btu's or more a month will yield a 70% efficiency level.

ASSIGNMENT NO. 7

1. What would be necessary to take into consideration if you were trying to decide to install a solar heating system in a home that was 15 years old?

The factors to consider in installing a solar heating system in a home that was 15 years old are:

1. Placement of the collector panels.
2. Placement of the storage medium.
3. Will the panels face directly south?
4. The collector should be able to be tipped back at the top so that it forms an angle with the horizontal equal to the latitude of your site plus 10 to 15 degrees.
5. Proper weatherization of the home and installation of added insulation and storm windows.
6. Is adequate sunlight available all winter long?

SOLAR ENERGY

TEST - SECTION I

NAME_____

DATE_____

GRADE _____

MULTIPLE CHOICE (choose best answer)

___ 1. Every _____ minutes, enough solar energy reaches the earth to supply the world's energy needs for one year.

a. 5 minutes b. 10 minutes c. 15 minutes d. 20 minutes

___ 2. Solar energy comes to us in a _____ state.

a. new b. cold c. hot d. diffuse e. direct

___ 3. Solar energy is an _____ energy source.

a. constant
b. intermittent
c. short term
d. long term
e. none of the above

___ 4. To heat your home by solar energy, you will need sunlight collectors that cover the equivalent of roughly _____your home's floor area.

a. one fourth b. one half c. three fourths d. equal to

___ 5. In most situations the average home buyer of today has _____ knowledge about home energy consumption.

a. a great deal b. a little bit c. very little d. no

___ 6. The wise home buyer will:

a. take the builder's word about built-in energy saving features.
b. ask questions and make inspections.
c. buy the home as soon as possible.
d. none of the above.

___ 7. The more intelligent approach to housing is to look at the _____ of the home.

a. front and back yards
b. kitchen space
c. lifetime cost
d. mortgage payment cost

___ 8. In __ to __ years the fossil forms of fuel may be unavailable.

a. 1 to 2 b. 5 to 10 c. 10 to 14 d. 15 to 25

___ 9. The _____ is the heart of the solar heating system.

a. thermostat control
b. storage tank
c. collector
d. duct system

___ 10. The most common type of collector is the

a. flat plate b. parabolic c. passive d. concentrator

___ 11. As soon as the collector plate warms up it will

a. shake and rattle.
b. lose heat back to the cool air around it.
c. run smoothly.
d. keep all the heat it absorbs.

___ 12. The result of putting a cover plate on a solar collector is

a. to reduce heat gain.
b. to keep the rain and dirt out.
c. to increase efficiency.
d. none of the above

___ 13. A collector is always most efficient when

a. it is used in the early morning.
b. it is used in the late afternoon.
c. heat is collected and quickly drawn off.
d. the collector spends part of the day in the shade.

___ 14. Always circulate the _____ air or water from storage back to the collector for reheating.

a. coldest
b. warmest
c. coldest then the warmest
d. warmest then the coldest

___ 15. A _____ is a device used to transfer warm temperature from one element to another.

a. iron
b. heat exchanger
c. refrigerator
d. none of the above

___ 16. The _____ type of heat exchanger is the most efficient for installation into a warm air duct system.

a. serpentine b. convex c. round d. finned coils

___ 17. To extract the heat from storage, air from _____ is passed through the storage medium and allowed to _____.

a. inside the home . . . return to the home.
b. outside the home . . . return to the collector.
c. outside the home . . . return to the home.
d. none of the above

___ 18. If the heat transfer medium is air, it is easiest to store the heat in a _____.

a. mud pit.
b. rock bin.
c. water storage tank.
d. none of the above

___ 19. As you extract heat from the storage medium the temperature of the water in the tank or the rock will

a. go up.
b. go down.
c. stay the same.
d. none of the above

___ 20. A "back-up" heating system can be a _____.

a. woodstove.
b. electric furnace.
c. gas furnace.
d. all of the above

___ 21. An advantage of a water-cooled collector system is that

a. it is more versatile.
b. it u s e s smaller pipes.
c. it has smaller power requirement.
d. all of the above
e. none of the above

___ 22. A disadvantage of a water-cooled collection system is that

a. a water system can leak.
b. it is more expensive.
c. it suffers from corrosion.
d. all of the above
e. none of the above

___ 23. For space heating using solar power

a. favor water-cooled collectors.
b. favor air-cooled collectors.
c. favor electric baseboards as heaters.
d. none of the above

___ 24. Most commercially made collector frames are made from

a. wood b. plastic c. fiberglass d. metal

___ 25. What can happen to foam type insulation if it gets too hot?

a. It can crack.
b. It can blow up.
c. It will emit a poisonous gas.
d. It will shrink.
e. all of the above
f. none of the above.

SOLAR ENERGY TEST - SECTION I

TRUE OR FALSE (answer by placing T or F on the line provided)

___ 1. If you have a 1400 square foot home you need 700 square feet of collector area.

___ 2. It will cost you no more than $5000 to use solar energy to heat your home.

___ 3. Various estimates terminate the world reserves of petroleum after 3004 A.D.

___ 4. Every increase in fossil fuels makes solar energy less attractive and practical.

___ 5. Solar energy education will only be necessary for our grandchildren.

___ 6. Most home builders spare no expense in making the homes they build as energy efficient as possible.

___ 7. A collector is a black plate that absorbs the sun's rays.

___ 8. The hotter a collector gets, the more heat it will lose to the surrounding atmosphere.

___ 9. A collector is always most efficient when heat is collected and quickly drawn off before it can build up and radiate away.

___ 10. For higher efficiency, keep the storage medium outside the home.

___ 11. In rock bin storage you should mix salt in with the gravel.

___ 12. If the rocks are large they will provide more area for heat exchange.

___ 13. If the rocks are too small they might pack together and restrict air flow.

___ 14. A back-up heating system is an unnecessary expense if you install a solar heating system.

___ 15. Corrosion is a problem for air-cooled collectors.

___ 16. Air systems can be more efficient.

___ 17. Air systems are easier to make.

___ 18. Aluminum is the best material to use in a water-cooled collector.

___ 19. Copper costs much more than aluminum.

___ 20. A cover plate will not improve efficiency.

SOLAR ENERGY TEST - SECTION I

LISTING

1. List four (4) component parts to a water-cooled flat plate collector.

   a. _____ c. _____

   b. _____ d. _____

2. List six (6) materials used in making a solar collector - water or air.

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

   f. _____

3. List three (3) types of concentrating collectors.

   a. _____ b. _____ c. _____

4. List three (3) necessary considerations before installing solar equipment on an older home

   a. _____

   _____

   b. _____

   _____

   c. _____

   _____

5. List two (2) materials preferred for use in the cover plate of a solar collector.

   a. _____

   b. _____

SOLAR ENERGY

TEST - SECTION II

NAME _____

DATE _____

GRADE _____

LISTING

1. List two types of solar water heating systems.

   a. _____ b. _____

COMPLETION

1. For the most efficient operation of a storage system for a solar heating unit the storage unit should be located in the _____.

2. Solar collectors should be tilted back at an angle equal to your latitude plus _____ degrees.

3. The electric blower for an air solar heating system should be capable of supplying air at a rate of _____ per minute per _____ of collector.

4. What type of thermostat is usually used on an air solar heating system?

   _____

5. Where should the thermostat probes be located?

   a. _____

   b. _____

6. Air should enter the rock bin for storage at the _____ and be drawn off from the _____ for use.

7. The thermal capacity for water raised 1 degree Fahrenheit in temperature is _____ per gallon.

MULTIPLE CHOICE

1. C	6. B	11. B	16. D	21. D
2. D	7. C	12. C	17. A	22. D
3. B	8. D	13. C	18. B	23. B
4. B	9. C	14. A	19. B	24. D
5. C	10. A	15. B	20. D	25. C

TRUE OR FALSE

1. T	6. F	11. F	16. T
2. F	7. T	12. F	17. T
3. F	8. T	13. T	18. F
4. F	9. T	14. F	19. T
5. F	10. F	15. F	20. F

LISTING

1. List four component parts to a water-cooled flat plate collector.

   a. cover sheet
   b. collector box
   c. absorber plate
   d. insulation

   Note: variations are acceptable, teacher decides correctness of answer according to material presented.

2. List six materials used in making a solar collector - water or air.

   a. copper tubing
   b. glass cover sheet
   c. fiberglass insulation
   d. wood or metal frame
   e. plywood backing of box
   f. flat black high temperature paint

   Note: variations acceptable.

3. List three types of concentrating collectors.

   Any three of following:

   a. Somor
   b. Abbot
   c. Ericsson
   d. Mouchot

4. List three necessary considerations before installing solar equipment on an older home.

   a. Adequate sunlight.
   b. Affordable payback period
   c. Is the home energy efficient enough to accept solar equipment?

   Note: variations acceptable.

5. List two materials preferred for use on the cover plate of a solar collector.

   Any two of following:

   a. 3M Flexiqard (TM)
   b. Kalwall Sunlite (TM)
   c. Filon Greenhouse Material (TM)
   d. Glass

LISTING

1. List two types of solar water heating systems.

   Any two of following:

   a. Thermosiphon
   b. Pressurized pump
   c. Drain down pressurized pump

COMPLETION

1. Basement
2. 10 to 15
3. 3 cubic feet . . . square foot
4. Differential
5. a. Back of the collector plate.

   b. Duct leading out of the storage bin back to the collector.

6. Bottom . . . . Top
7. 8.34

Dear Teacher:

The evaluation of the completed materials is a critical step in the curriculum development process. It is required that all recipients of the materials prepared by the Alternative Energy Curriculum Project furnish such an evaluation. After you have had time to review this learning packet, complete this questionnaire and return it to the Arkansas Research Coordinating Unit.

This evaluation is for: (Check (✓) one)

( ) Alcohol Fuels ( ) Nuclear Energy ( ) Wind Power

( ) Conservation ( ) Solar Energy

Evaluate each section of the learning packet by placing a check (✓) in the Favorable or Unfavorable column. If the evaluation is Unfavorable, please state the reason in the space beside the section name.

Favorable	Unfavorable		
( )	( )	Information Section	_____
( )	( )	Instructional Materials	_____
( )	( )	Student Study/Assignment Sheets	_____
( )	( )	Tests	_____

Evaluate the following characteristics of the learning packets by placing a check (✓) in the appropriate response.

Readability: ( ) Too High ( ) Too Low ( ) Right Grade Level

Material Length: ( ) Too Long ( ) Too Short ( ) Correct Length

Technical Level: ( ) Too Technical ( ) Too General ( ) Right Technical Level

---

Do you plan to use this material in your classes? Check (✓) Will or Will Not. If Will, supply requested information. If Will Not, state reasons.

( ) Will

Name of Class _____

Grade Level of Class _____

School Name _____

( ) Will Not

Reasons _____

If additional Alternative Energy Curriculum materials would be of use in your classes, check (✓) those energy topics which should be developed.

( ) Bio-Mass ( ) Fuel Cells ( ) Methane ( ) Coal ( ) Geothermal

( ) Other _____

Thank you for your evaluation. Fold this questionnaire so the return address is on the outside. Seal with a small piece of tape. Place a first class stamp in the upper right hand corner and mail.

IMPORTANT !!!

EVALUATION QUESTIONNAIRE

CE029147

Place
Stamp
Here

Arkansas Research Coordinating Unit
Education Building West, Room 305-D
Arkansas Department of Education
Little Rock, Arkansas 72201

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